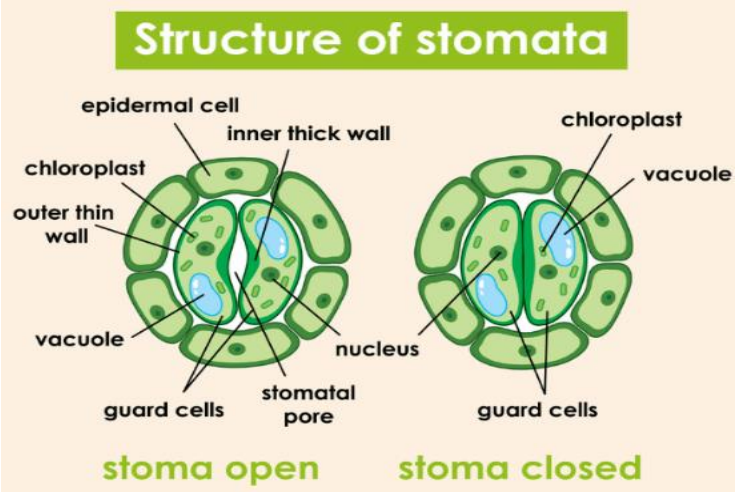
Chapter 3 : Transpiration

Loss of excess of water in the form of water vapour from the aerial part of the plant body mostly through the leaves is known as transpiration. The loss of water due to transpiration is quite high, 2 litres per day in Sunflower, 36-45 litres in Apple and up to 1 tonne per day in Elm tree. Rather 98-99% of the water absorbed by a plant is lost in transpiration. Hardly 0.2% is used in photosynthesis while the remaining is retained in the plant during growth.

1. Definition

The loss of water from the aerial parts of the plant in the form of water vapours is called transpiration. Leaves are the principal organs of transpiration and most of the transpiration takes place through their stomata.

2. Structure of stomata



The opening and closing of the stomata are essential for a plant's survival and growth, as they help balance water loss through transpiration and the intake of carbon dioxide needed for photosynthesis. The structure of stomata consists of several key components :

Guard Cells: These are two specialized kidney-shaped cells that surround the opening and closing of the stomatal pore. They change shape to regulate the pore's size in response to environmental factors like light, humidity, and carbon dioxide levels.

Stomatal Pore: The actual opening or pore through which gases enter and exit. It's formed between the two guard cells and can open or close to regulate gas exchange.

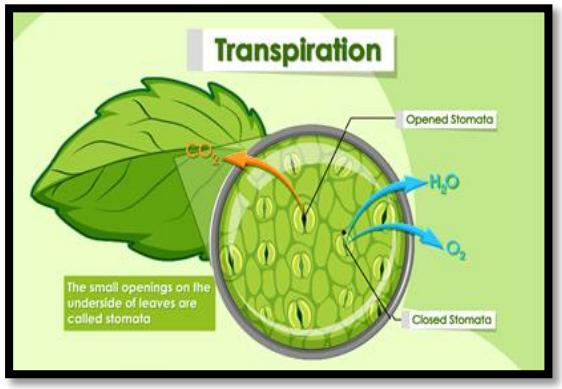
Epidermal Cells: These are the surrounding cells that protect and support the stomata. They provide structural integrity to the leaf surface.

Cuticle: A waxy layer covering the epidermal cells and stomata, which helps reduce water loss and prevents unwanted substances from entering the plants.

Subsidiary Cells: These are cells adjacent to the guard cells and may play a role in regulating stomatal function, especially in response to environmental cues.

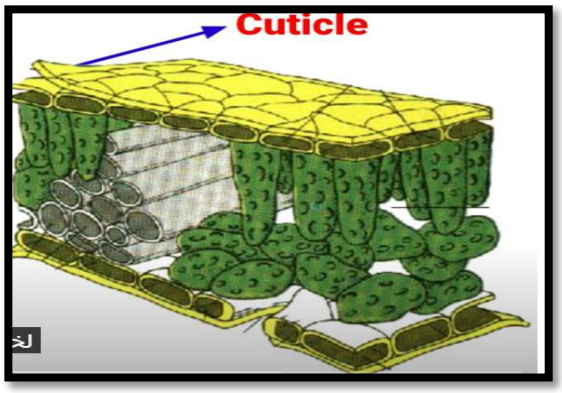
3. Types of transpiration

• **Stomatal Transpiration:** The transpiration process which occurs through stomata is called Stomatal transpiration.



- ✓ It is most important type of transpiration constitutes 50-97% of total transpiration.
- ✓ The stomata are found numerously on the leaf surface. Few stomata also found on green stem, flower and fruits.
- ✓ This type of transpiration only occurs in its presence of sunlight (in daytime). Because stomata open in the present of sunlight and close in the darkness.

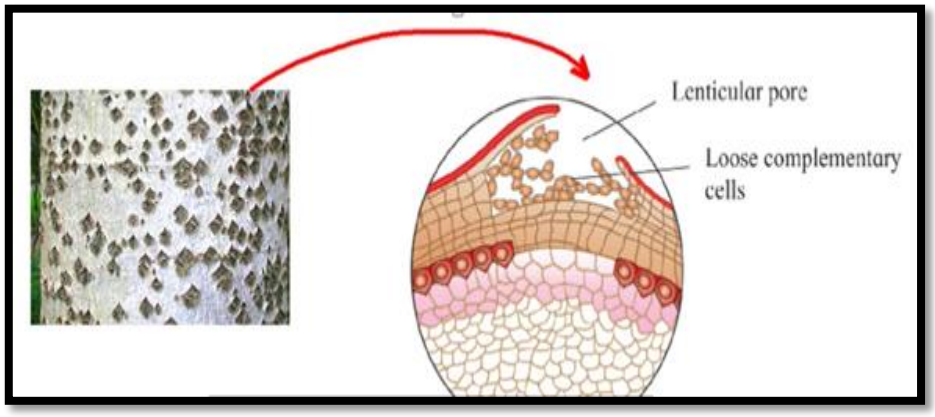
• **Cuticular Transpiration:** 3-10% of absorbed water is lost this pathway.



Transpiration that occurs through the cuticle or cracks of thin cuticle layer of leaves and stems is known as cuticular transpiration. This is a day-night process. In this process, 5-10% water is given out in the form of vapor.

- ✓ This transpiration continues throughout day and night.

• **Lenticular Transpiration:** At times, water is also lost through the lenticles of stems and fruits.



- ✓ It is found only in woody stems and some fruits where lenticels occurs.
- ✓ Constitutes major part of water loss by deciduous trees during leafless stage.
- ✓ Occurs continuously day and night and there is no mechanism to stop or reduce it.
- ✓ Total water loss through them is only fraction of total i.e. 0.1%.

4. Opening and closing of Stomata (Mechenism of stomatal movement)

- ✓ Opening and closing of stomata is governed by turgor changes of the guard cells.
- ✓ Three main theories explains the stomatal movements

1. Hypothesis of guard cell photosynthesis.

2. Starch sugar Interconversion Theory.

3. Malate or K+ ion Pump Hypothesis (Modern Theory).

4.1. Hypothesis of guard cell photosynthesis

- ✓ Guard cell contain chloroplast . Chloroplast perform photosynthesis during day time and thus produces sugar .
- ✓ Solute concentration of guard cells **increases** due to sugar as compared adjacent epidermal cells.
- ✓ Thus absorption of water by guard cells from epidermal cells . Turgid guard cells bent outwardly and stomata open.

4.2. Starch sugar Interconversion Theory

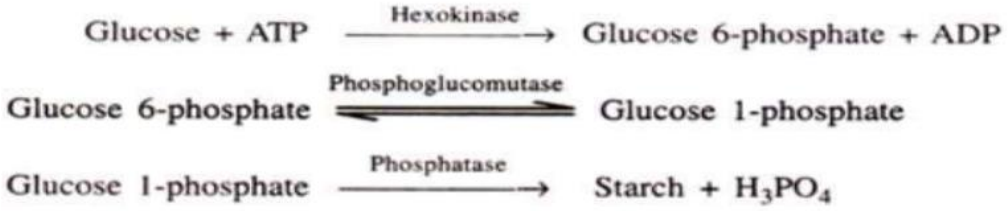
- ✓ Proposed by Sayre.
- ✓ Guard cells contains starch when stomata are closed.
- ✓ Starch is changed to sugar.
- ✓ In the morning carbon dioxide concentration is low (due to increase in rate of photosynthesis).
- ✓ Reduced carbon dioxide leads to increase in PH (due to loss of carbonic acid).

$$\text{Starch} + n\text{H}_3\text{PO}_4 \xrightarrow{\text{Phosphorylase}} n\ \text{Glucose 1-phosphate}$$

$$\text{Glucose 1-phosphate} \underset{}{\overset{\text{Phosphoglucomutase}}{\rightleftharpoons}} \text{Glucose 6-phosphate}$$

$$\text{Glucose 6-phosphate} + \text{water} \xrightarrow{\text{Phosphatase}} \text{Glucose} + \text{H}_3\text{PO}_4$$

- ✓ Hence glucose increases the Osmotic Pressure of guard cells , withdraw water from epidermal and subsidiary cells .
- ✓ On absorption of water guard cells swell up and stomata open.
- ✓ Above reaction is reversible.



- ✓ Reversible reaction requires the lowering of PH.
- ✓ Decrease PH leads to phsphorylation of glucose.
- ✓ As a result of osmotic concentration of guard cell is falls and loss of turgidity of guard cell hence stomata closed.

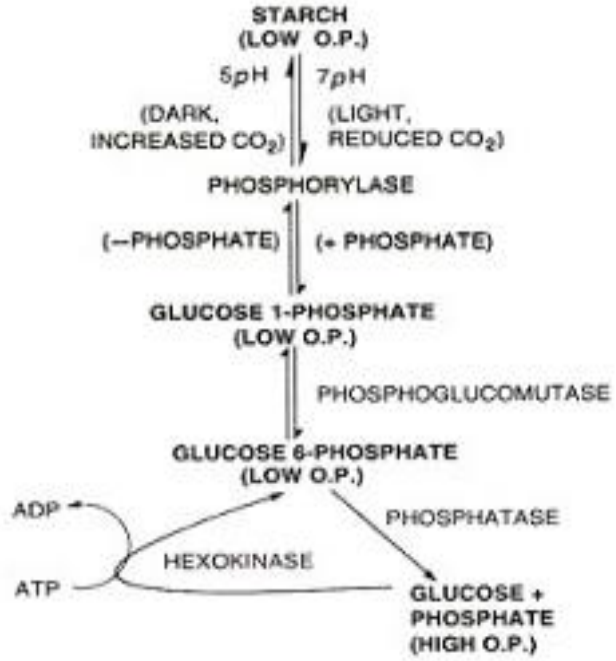


Fig. 11.36. Development of high and low osmotic pressures in guard cells through starch hydrolysis theory.

Fig 1: Development of high and low osmotic pressure in guard cell through starch hydrolysis theory

Objection:

- ✓ Starch and sugar conversion is chemically slow while stomata opening is rapid process.
- ✓ Blue light is more effective for stomatal opening not explained by starch sugar conversion Theory.

During day time	During night time
In presence of light	In absence of light
Guard cells use CO_2 i.e. photosynthesis	No photosynthesis
Fall in the CO2 concentration	Rise in the CO2 concentration
Increase in the pH (<7) in guard cells	Decrease in the pH (>5) in guard cells
Hydrolysis of starch to sugar	Conversion of sugar to starch
Rise in the osmotic potential of guard cells	Fall in the osmotic potential of guard cells
Endosmosis	Exosmosis
Guard cells become turgid	Guard cells become flaccid
Stoma opens	Stoma closes

4.3. Malate or K+ ion Pump Hypothesis (Modern Theory).

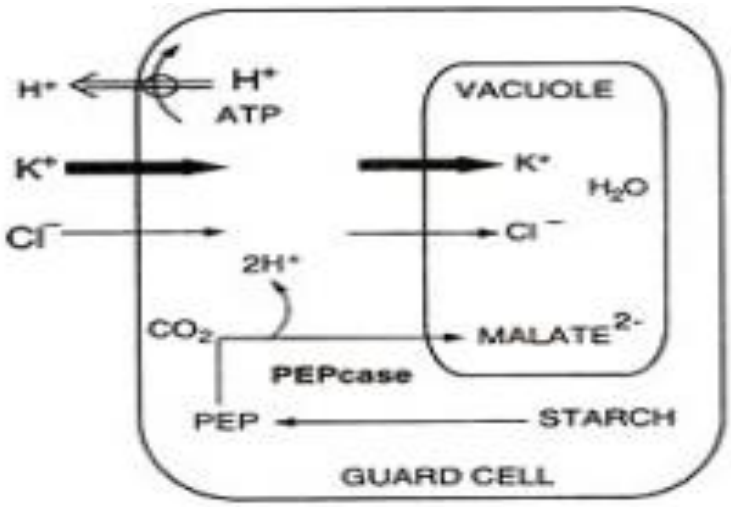


Fig. 11.37. Role of K^+, Cl^- and malate in increasing osmotic concentration (decreasing water potential) of guard cells.

K+ ion theory (potassium pump theory) was proposed by Levitt in 1974. He states that:

- **During light**:- Starch is converted to PEP (phosphoenol pyruvic acid) which combines with CO to form oxaloacteic acid (OAA) and ánally to malic acid. This malic acid dissociates into malate anions and H ions in guard cells. H ions are transported to subsidiary cells and in exchange of which K ion move inside guard cells. This is called ion exchange. K ions are balanced by malate ions present in guard cells and also by taking in some Cl ions. This ion exchange occurs by the expenditure of ATP energy. Increased concentration of K and malate ions in the guard cells vacuole, will cause sufácient osmotic pressure to absorb water from surrounding cells. This in turn will increase turgor pressure of guard cells and lead to the opening of stomatal pores.

- During dark:- Carbon-dioxide concentration increase in sub-stomatal spaces because of initiation of respiration which will prevent the H - K ion exchange. Due to this malate ions present in the vacuole of guard cells combine with the H+ ions and form malic acid. Increase in the concentration of malic acid will inhibit its synthesis. K ion move out of guard cells, osmotic pressure decrease. Water will move out of guard cells into subsidiary cells which makes cell âaccid and cause the closure of stomatal pore.

5. Factor affecting rate of Transpiration

- ✓ Atmospheric Humidity is inversely proportional to rate of transpiration.
- ✓ Temperature is directly proportional to rate of transpiration.
- ✓ Light intensity is directly proportional to rate of transpiration.
- ✓ Wind velocity is directly proportional to rate of transpiration.
- ✓ Carbon dioxide concentration is inversely proportional to rate of transpiration.
- ✓ The factors like structure of leaf area of transpiring surface, number of stomata, orientation of leaf are included in the category.