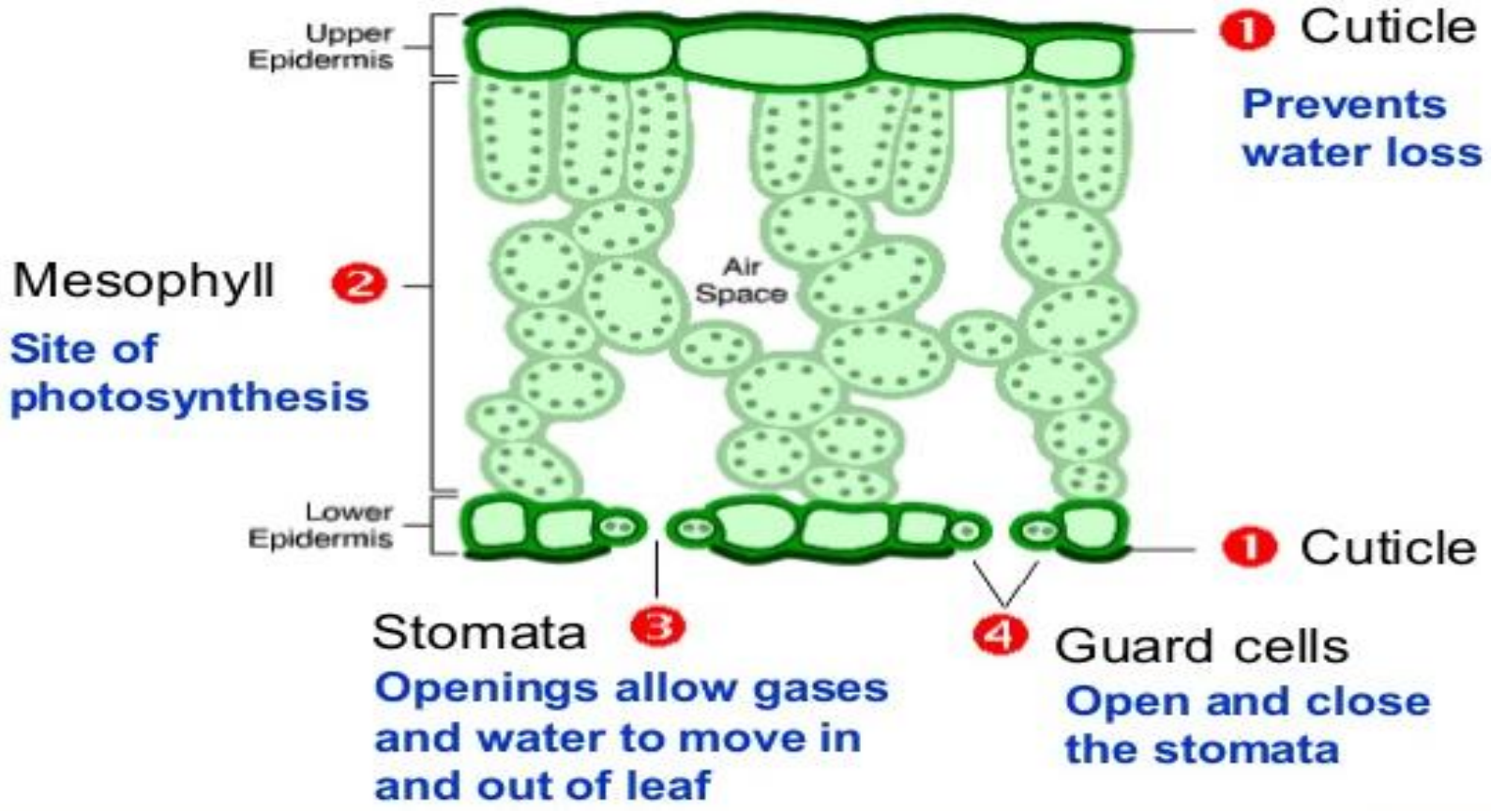
Transpiration

Class: GE4

Introduction

- Transpiration is a process in which large amounts of water are lost continuously in the form of water vapour to the atmosphere from the evaporating surface of the aerial parts of plants.



Anatomy of leaf

Types of transpiration

- **Stomatal Transpiration**: Most (approx. 90%) of the absorbed water is lost via this pathway. Water moves from the xylem ends to the leaf parenchyma and from its surface water evaporates to the atmosphere
- **Cuticular Transpiration**: 3-10% of absorbed water is lost this pathway.
- **Lenticular Transpiration**: At times, water is also lost through the lenticles of stems and fruits.

However, the water lost through cuticular and lenticular pathways are insignificant compared to the the stomatal transpirational pathway.

Factors affecting transpiration:

Internal factors

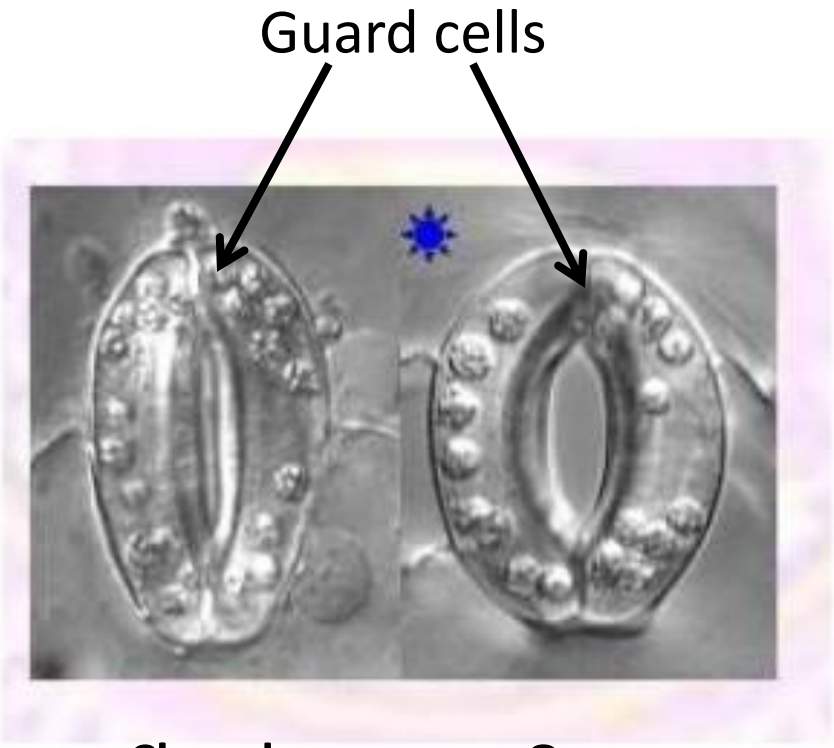
- Number of leaves
- Number of stomata/leaf
- Size of the leaf
- Presence of cuticle
- Root-shoot ratio

External factors

- Temperature
- Light
- Relative humidity
- Wind and air movement
- Soil-moisture availability
- Type of plants

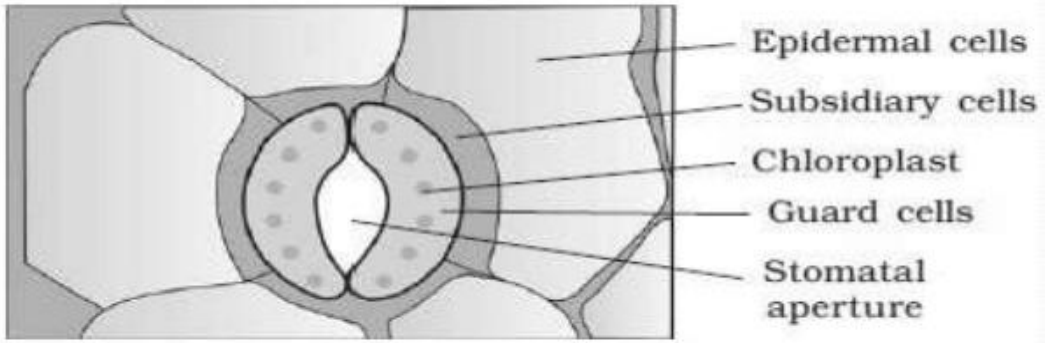
- The epidermal surface of a leaf bears a great number of pores called stomata.
- The stomata are microscopic and are bordered by two specialized epidermal cells called guard cells, which control the opening and closing of stomata.
- The stomatal movement is generally understood to be a direct response to increase or decreases in the osmotic potential of the guard cells.
- As a result of this changes in water potential cause water to move in or out of the guard cells.

- If water moves in, the cells expand, the stoma opens.
- If water moves out, cells go faccid, and the stoma gets closed.



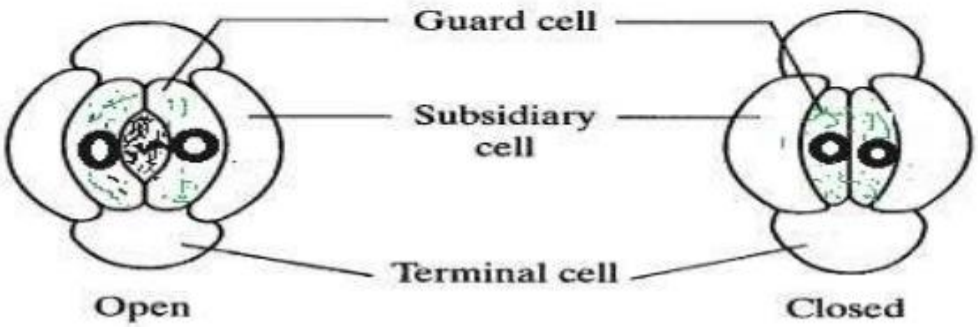
Closed Stomata **Open Stomata**

Stomata



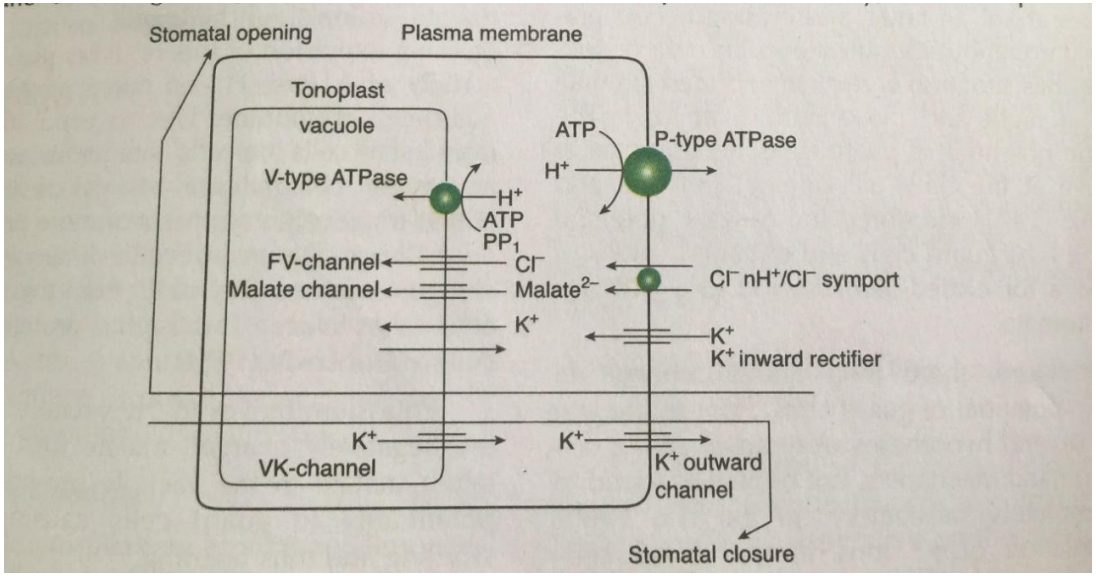
>> Open Stomata Happen At Day Time
Closed Stomata Happen At Night Timing

>>At Open Time Transpiration Occur
At Closed Timing No Transpiration Occur



- Guard cells become turgid when swollen with water causing an opening in the stoma
- When they lose water they become flaccid causing the stoma to close
- Water is stabilized in and out of the guard cells as potassium ions are transported across the plasma membrane, regulating the amount of water and ions taken in.

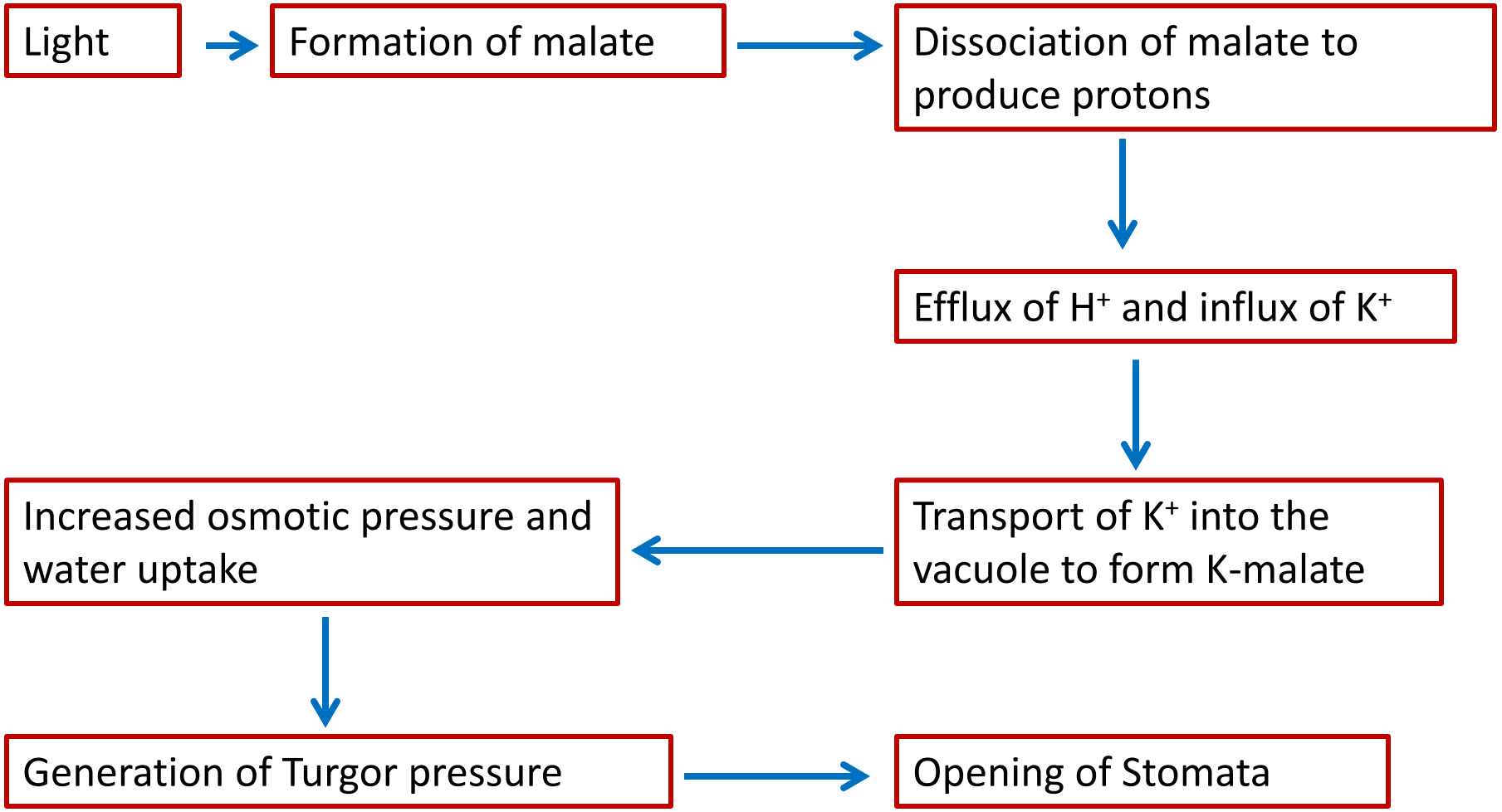
Mechanism of Transpiration



A scheme for different ionic events for opening and closing of stomata

- Imamura discovered the role of K^+ in stomatal opening.
- Fujino correlated the stomatal opening/closing during the day and night consecutively with the active transport of K^+ in and out of the guard cells.
- Most important event in stomatal opening is the activation of plasma membrane (PM) proton extruding ATPase to hyperpolarize the membrane potential negative inside. This situation activates the potassium ion specific inward rectifying channel and also strengthens the driving force for the voltage-sensitive passive K^+ inward uptake. Ultimately K^+ is transported into the vacuole through the activation of a H^+/K^+ antiporter.
- During darkness, protons are excreted from the guard cells by the activity of ATPase -proton pump.
- In some conditions, K^+ uptake is against an electrochemical potential gradient indicating that K^+ cross the membrane by means of active processes .

Series of events leading to stomatal opening



Steps

- Starch produced from photosynthesis disappears when the stomata are open. It is then hydrolyzed to form glucose, which through gycolysis produces phosphoenol pyruvate (PEP). Carboxylation of PEP leads to the formation of malate, which dissociates into malate ion and hydrogen cation (H^+).
- During the stomatal opening, expulsion of this H^+ takes place by the activity of ATPase proton pump present in the guard cell membrane.
- Due to expulsion of protons from guard cells, the guard cells/ interior becomes more negatively charged and its pH in increased which triggers the synthesis of more malic acid.
- To balance the guard cell's internal negative charge, passive influx of potassium ion (K^+) from the subsidiary cells takes place. This is called proton transport concept. Potassium moves to the vacuole to balance the negatively charged malate ions. The potassium malate in the vacuole leads to increased osmotic pressure (OP) in the guard cells which in turn generates turgor pressure causing stomatal opening.
- In the dark, the sequence of events is opposite leading to stomatal closure. The potassium and chloride ions are excised out of the guard cells. The malate is decarboxylated to carbon-dioxide and pyruvate which through the reversal of glycolysis is converted to sugar and finally incorporated to starch again. As a result, water osmosis out of the guard cells to bring about flaccidity, leading to their closure.
- Abscisic acid acts as the chemical signal for drought-induced stomatal closure. It causes the closure of the stomatal pores which are held open by the turgor pressure of guard cells. Since the ion channels are the major players in regulation of guard cells, there might be a tentative link between ABA and ion channel regulation.

Significance of transpiration

I. Transport of minerals:

- Usually, high transpiration rates cause high rates of mineral absorption. It is generally held that minerals absorbed by the plant from the soil usually move up through the plant via transpiration stream.
- The amount of minerals reaching the leaves is dependent upon the rate of absorption of minerals by the roots rather than the rate of transpiration.
- Rates of transpiration do not seem to affect the availability of minerals in the leaf. On the contrary when the mineral in the soil are in abundance then the rate of transpiration is vital for their translocation.

II. Lowering of leaf temperature:

- Transpiration of water from a surface of the leaf lowers the temperature of that organ since the loss of water molecules of a relatively high kinetic energy; the molecules having highest kinetic energy are the first to evaporate.
- Rough estimates show around that transpiration removes about 600 calories per gram of evaporated water.
- There are other ways e.g., radiation and convection by which heat is removed. If transpiration stops, there would be an enhanced loss of heat by radiation and convection because of the increased leaf temperature.

Significance of transpiration

III. Optimum turgidity:

- It is generally argued that there is an optimum level of water potential within the plant. Many and varied functions are slowed down or are rendered inefficient both above or below this level.
- In the absence of transpiration, plants tend to become over turgid and will cease to grow. Similarly when the water potential becomes highly negative growth also stops.