

JURONG WEST SECONDARY SCHOOL  
SECONDARY FOUR/FIVE – SCIENCE BIOLOGY  
**Chapter 9.2: TRANSPORT IN PLANTS**

**Learning Outcomes:**

Candidates should be able to:

- a) **identify (label)** the cellular and tissue structure of a dicotyledonous leaf, as seen in transverse section using the light microscope and describe the significance of these features in terms of their functions, such as the
  - distribution of **chloroplasts** for photosynthesis
  - stomata and mesophyll cells for gaseous exchange
  - **vascular bundles for transport (xylem + phloem)**
- b) **identify** the positions of and **state the functions** of **xylem vessels and phloem** in sections of a herbaceous dicotyledonous leaf and stem, under the light microscope
- c) explain how the **structure** of a **root hair cell** is suited for its **function** of water and ion uptake
- d) State that **transpiration** is the loss of **water vapour** from the **stomata**
- e) **(essay)** Briefly **explain** the movement of water through the **stem** in terms of **transpiration pull**
- f) investigate and explain:
  - the effects of variation of air movement, temperature, humidity and light intensity on transpiration rate
  - how wilting occurs

Define the term translocation as the transport of food (mainly sucrose) in the phloem tissue

**Quick recap from previous chapter**

What do you remember from your lesson on Nutrition in Plants?

**Where** does photosynthesis take place in the plant?

**What** are the necessary elements for photosynthesis?

**How** do water and minerals reach the leaves?

**How** do manufactured food reach the leaves?

**Linking it back to Transport in Plants:**

1. What are the two transport vessels that you know in plants:
  
2. Importance of these transport vessels:

3. Which parts of the plants do you find these transport vessels?

**b) identify the positions of and state the functions of xylem vessels and phloem in sections of a herbaceous dicotyledonous leaf and stem, under the light microscope**

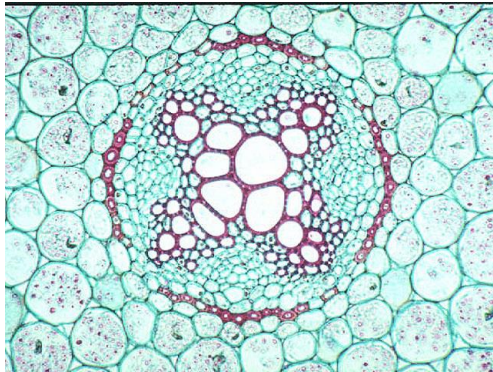
**ACTIVITY:**

What are vascular bundles? \_\_\_\_\_ **transport vessels** \_\_\_\_\_

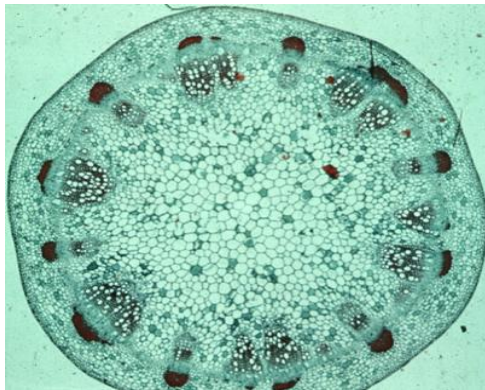
You will be learning about the vascular bundles in different parts of the plants.

Identify the xylem and phloem and which part of the plant, the vascular bundle belongs to.

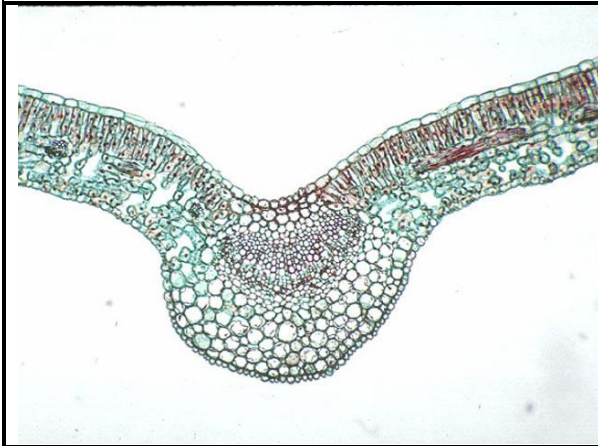
Vascular bundle in plant's \_\_\_\_\_ **root** \_\_\_\_\_



Vascular bundle in plant's \_\_\_\_\_ **stem** \_\_\_\_\_



Vascular bundle in plant's \_\_\_\_\_ **leaf** \_\_\_\_\_



- a) **identify the cellular and tissue structure of a dicotyledonous leaf, as seen in transverse section using the light microscope and describe the significance of these features in terms of their functions, such as the**
- distribution of chloroplasts for photosynthesis
  - stomata and mesophyll cells for gaseous exchange
  - **vascular bundles for transport**

## What is transport?

- Transport is the movement, circulation or flow of substances within living organisms.

## Functions of the plant transport system

- A way of moving water and mineral salts from the roots to the leaves, [XYLEM]
- A way of moving sucrose and amino acids from the leaves to other parts of the plant while it is photosynthesising. [phloem]

## Substances transported in plants

1. Useful ions and small molecules such as  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{NO}_3^-$ ,  $\text{C}_6\text{H}_{12}\text{O}_6$ , and amino acids, dissolved in water for constructional or other functional purposes.
2. Waste products like catabolised enzymes and hormones for excretion.
3. Gases or vapours e.g.  $\text{O}_2$ ,  $\text{CO}_2$  dissolved in water and water vapour.

### Stretch yourself

- How is the plant transport system different from the human circulatory system?  
*In case of human body, the circulation of fluids takes place due to the presence of heart, which acts as a pump.*  


---

*In comparison, there is no pumping mechanism in a plant and the water movement occurs mainly via transpiration pull.*  


---

# The transport tissues

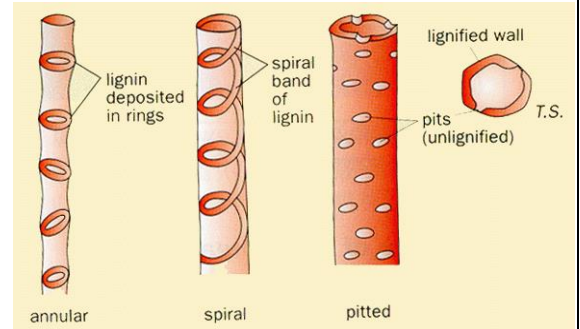
The 2 transport (vascular) tissues of flowering plants are the xylem and phloem.

- **Xylem** transports **water and mineral salts** from the roots to all parts of the plant.
- **Phloem** transports **manufactured food (sucrose and amino acids)** from the leaves to other parts of the plant.

## 1. The Xylem vessel

**Characteristics (structure)** of xylem vessels:

1. Xylem vessels are **long and narrow**.
2. They are **hollow** and are without protoplasm (therefore dead cells).
3. The cells are **joined end to end**, without any cross walls and extend as continuous tubes from roots to stems and into the leaves.
4. The cellulose cell wall is strengthened by **lignin**.



**Xylem vessel showing different patterns of lignification**

The xylem vessels have 2 functions:

1. **Conducting water**, with its dissolved mineral salts, from the roots to the stems and leaves.
2. Providing **mechanical support** within the plant.



How the xylem is **adapted** for its function:

1. It has an **empty lumen** without protoplasm. This **reduces resistance** to water flowing through the xylem, allowing water to be conducted / **transported** up the plant.
2. It has **lignified cell walls** to provide **mechanical support** for the plant.
3. ~~The narrow lumen helps to draw water up by capillary action\* (\*See TB page 195)~~

## 2. The Phloem vessel

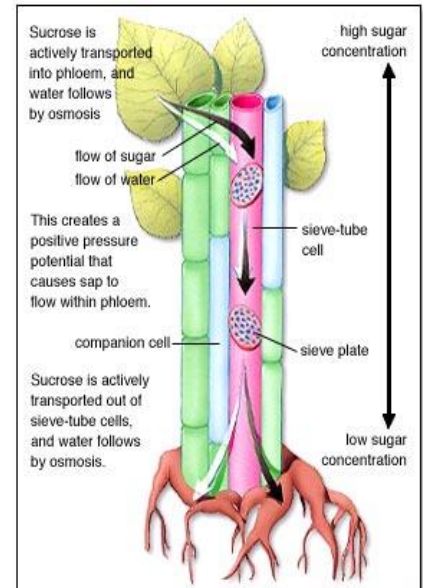
Characteristics of phloem vessels:

1. Phloem is a **living tissue**
2. They have cytoplasm

The function of the phloem vessel:

- **Phloem** transports manufactured food (**sucrose and amino acids**) from the leaves to other parts of the plant.
- By **Translocation** (Refer to the diagram)

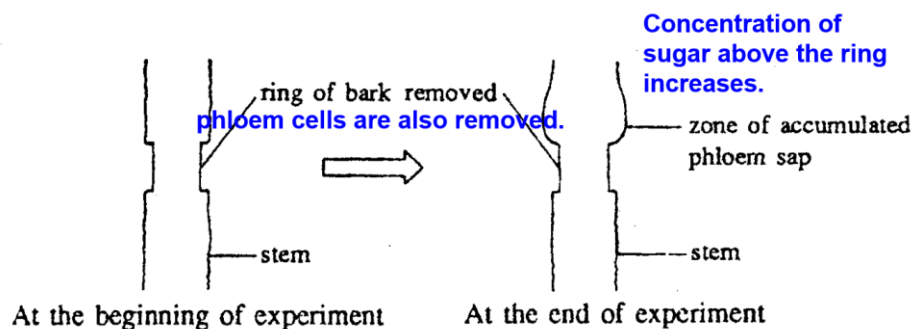
**Definition: Translocation** is the movement of manufactured food such as sucrose from the green parts of the plants to the rest of the plant by the phloem vessels.



### Translocation Studies (refer to TB pages 189 – 191)

Discuss with your partner, how these experiments can help to determine the rate & direction of movement of substances?

#### Experiment 1: Ringing



#### Inference:

**Phloem carries materials from the leaves to other parts of the plant.**

**Experiment 2: Radioactive isotopes**

Low-level radioactive isotopes emit radioactivity, which can be measured.

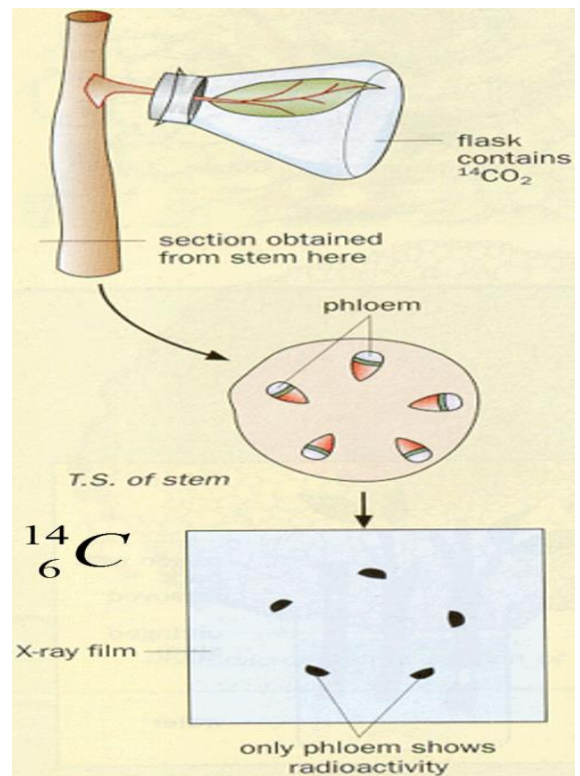
Plants absorb the isotope through their leaves. The radioactive carbon is converted to glucose.

**Inference:    carbon dioxide is needed to produce glucose. Manufactured food (sucrose) is transported by the phloem.**

---



---

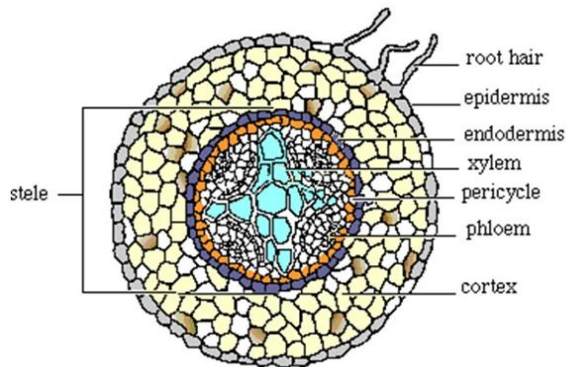
**Experiment 3: Using Aphids in Translocation Studies**

→ Refer to TB page 190

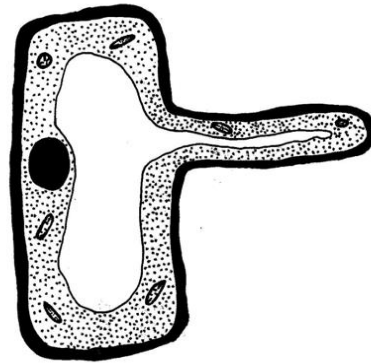
**c) Explain how the structure of a root hair cell is suited for its function of water and ion uptake**

## The structure & function of the root hair

T.S of Dicot Root

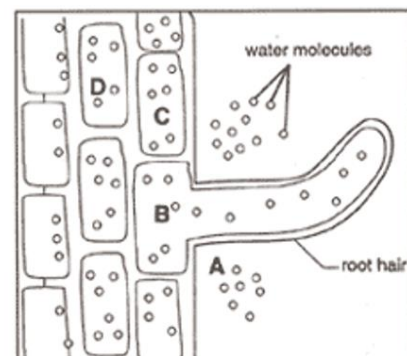
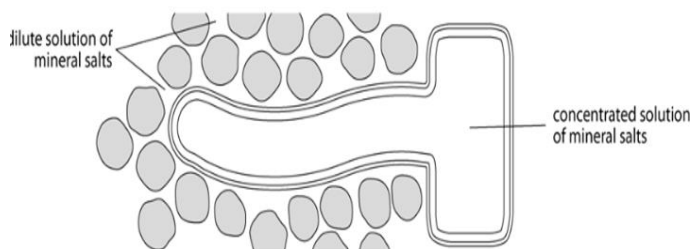


Root hair cell



1. **Long and narrow extension** / **protrusion** from the epidermal cells.
  - To **increase surface area to volume ratio** to increase **rate** of absorption of water.
2. **Large central vacuole.**
  - To store more water and minerals.
3. Cell sap contains sugars, amino acids and salts.
  - It is **more concentrated** than soil → **lower water potential** than soil
  - Water can enter cell by **osmosis**.

## Entry of water into plant from roots



- **Water** in the soil has a **higher water potential** than the root hair cell sap. Water is absorbed into the root hair cells by **osmosis**.
- The entry of water dilutes the sap. Water will then pass through neighbouring cells via **osmosis** until it reaches the **xylem** and moves up the plant.
- **Dissolved mineral salts** are absorbed by **diffusion** and **active transport**.



Scan to watch  
animation

<https://youtu.be/sIOcTUA0egg>

## Movement of water up the plant

- Water enters the open-ended xylem vessels in the central part of the root.
- Xylem tissues form an almost continuous system of thin woody (lignified) tubes connecting the roots with the stem and leaves.
- Water moves up mainly by **transpiration pull**.

### What is transpiration pull?

- The **suction force** due to **transpiration** is known as transpiration pull
- **Note: transpiration pull is not the same as transpiration!**
- It is the **main force** in drawing water and mineral salts up the plant.
- Other factors drawing water up the plant include:
  - **Root pressure**
  - **Capillary action**

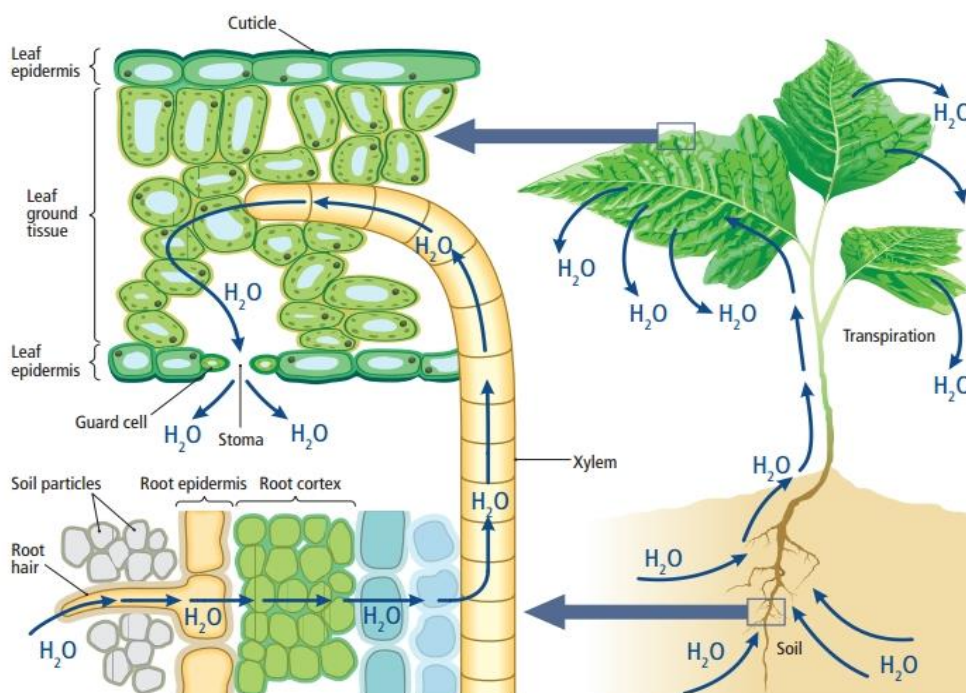
**d) State that transpiration is the loss of water vapour from the stomata**

## Transpiration

**Definition:** Loss of **water vapour** from the aerial parts of the plant especially through stomata of the leaves.

- Water continuously move out of the mesophyll cells to form a **thin film of moisture** on the surface of the spongy mesophyll cells.
- **Water** **evaporates** from thin film of moisture to become **water vapour** in the **intercellular air spaces**.
- Water vapour then **diffuses** out of the leaf through the **stomata**.
- As water evaporates from mesophyll cells, the **water potential in the cell sap decreases**. It draws in more water via **osmosis** from the xylem, which results in **transpiration pull**.

## The transpiration stream



### Importance of **transpiration**

- Helps to cool the plant
- Helps in transport of water and mineral salts to the rest of the plant. Helps to maintain cell turgidity by providing constant water supply to the cells

### **f) investigate and explain:**

- **the effects of variation of air movement, temperature, humidity and light intensity on transpiration rate**
- **how wilting occurs**

### Activity (Refer to **TB page 196 - 199** for more experiments)

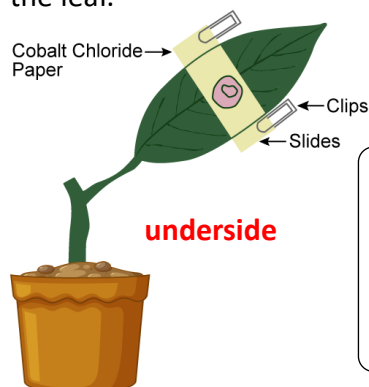
Cobalt chloride paper is blue in colour, it turns pink when in contact with water.

Clip the Blue-cobalt chloride paper on the surface of the leaf.

Record your observation in the space below.

Observation: blue cobalt chloride paper turns pink on the underside of the leaves faster

Inference: more stomata is found on the underside of the leaves



Scan to see photos of the colours of cobalt chloride paper in this experiment

## Investigating rate (speed) of transpiration (refer to TB page 202-204)

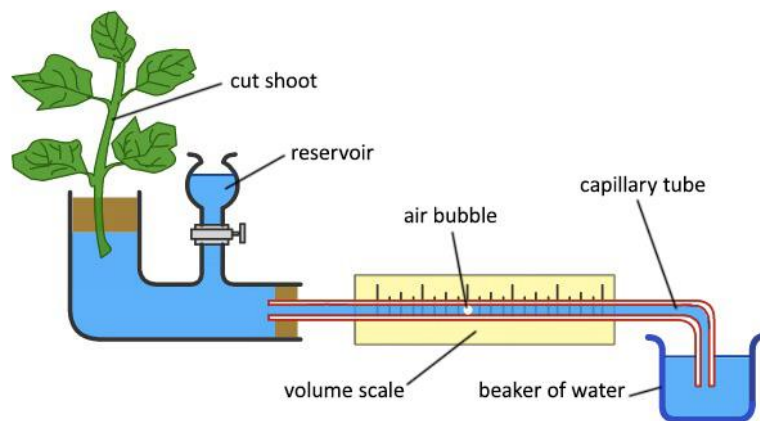
A student set up a potometer to investigate the **amount of water** taken up by a leafy shoot. The **distance** that the air bubble travelled along the capillary tube, was measured every **two minutes (must be divided by time)**.

Watch videos

<https://www.youtube.com/watch?v=fxhCtnfxJVk>

&

[https://www.youtube.com/watch?v=gQG8UCPaF\\_I](https://www.youtube.com/watch?v=gQG8UCPaF_I)



Observation of the position of air bubble:

**It moves towards the cut shoot**

What is the assumption that this experiment makes?

**It assumes that amount of water taken in is the same as amount of water lost.**

**However, this may not be true as the plant also uses water for photosynthesis and to maintain turgidity.**

What is the purpose of the reservoir?

**To reset the experiment by adding more water into the setup.**

How do we calculate **rate** of transpiration?

**Note the initial and final distance travelled by the air bubble over a fixed period of time.**

**Divide distance travelled by time.**

# Factors affecting Transpiration

(TB pg 205 – 207)

## 1. Humidity of the air

- Humidity is the concentration of water vapour in the air.
- Higher humidity **lowers the diffusion gradient** for water vapour to diffuse out, thus lowering the rate of transpiration
- The more humid the air, the slower the rate of transpiration.

## 2. Temperature of the air

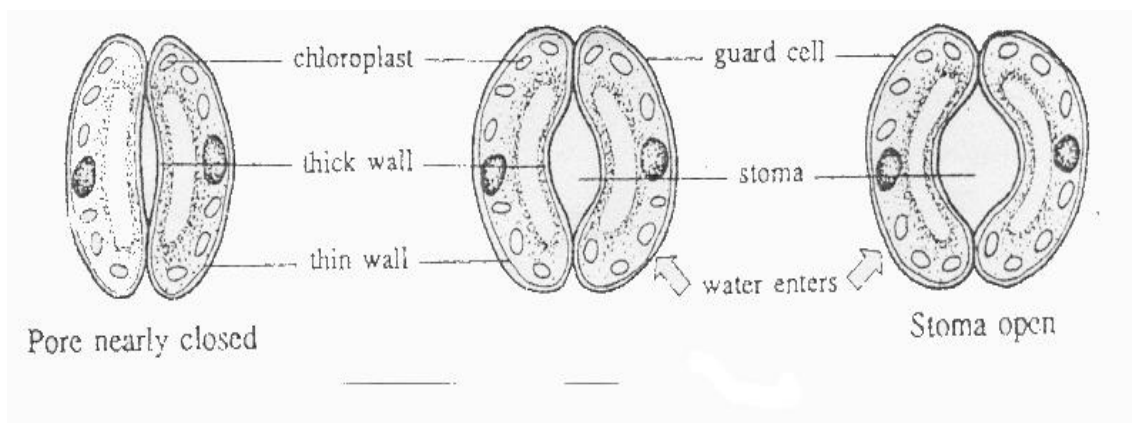
- A rise in temperature of the surroundings increases the rate of evaporation of the thin film of moisture
- thus the rate of transpiration is greater.

## 3. Wind speed

- The stronger the wind, the higher the rate of transpiration.
- Wind blows away the water vapour surrounding the leaf, creating a steeper diffusion gradient for more water vapour to diffuse out of the leaf

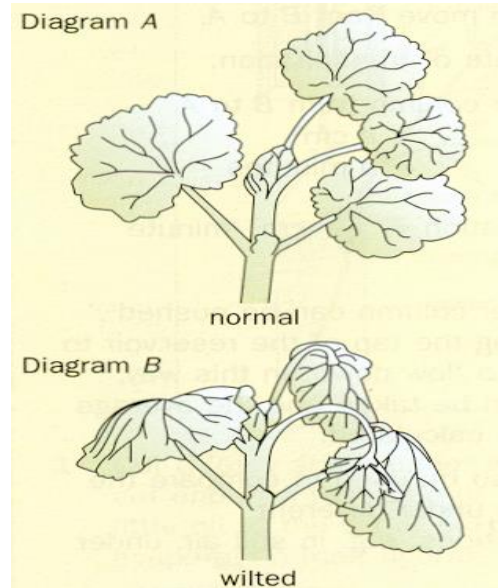
## 4. Light intensity

- As light intensity increases, rate of photosynthesis increases.
- More glucose is produced. This lowers the water potential inside the guard cell.
- There is a net movement of water into the guard cell via osmosis.
- Guard cell becomes turgid, size of stomata increases.
- More water vapour diffuses out of the leaf, rate of transpiration increases.



# Wilting

- **Wilting** occurs when the **rate of transpiration exceeds the rate of absorption of water**.
- Plants become flaccid due to excessive transpiration causing the cells in the plant to lose their turgor.
- Advantages:
  - Rate of transpiration is reduced because the leaf folds up **reducing the surface area** that is exposed to sunlight.
  - This causes guard cells to be flaccid and stomata close.
- Disadvantages:
  - Rate of photosynthesis is reduced because water becomes a limiting factor.
  - Due to the closed stomata, amount of carbon dioxide entering the leaf is also reduced.



## Extension:

Discuss with your partner, how do plants living in extreme weather conditions such as the desert maintain their water potential in cells?

---



---



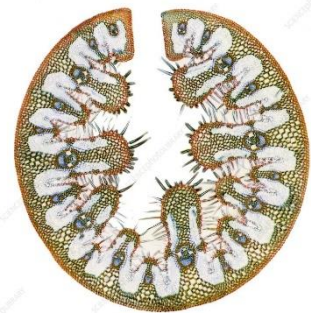
---



---



---



Light micrograph  
of a marram grass

*The End*