TRANSPORT IN PLANTS.

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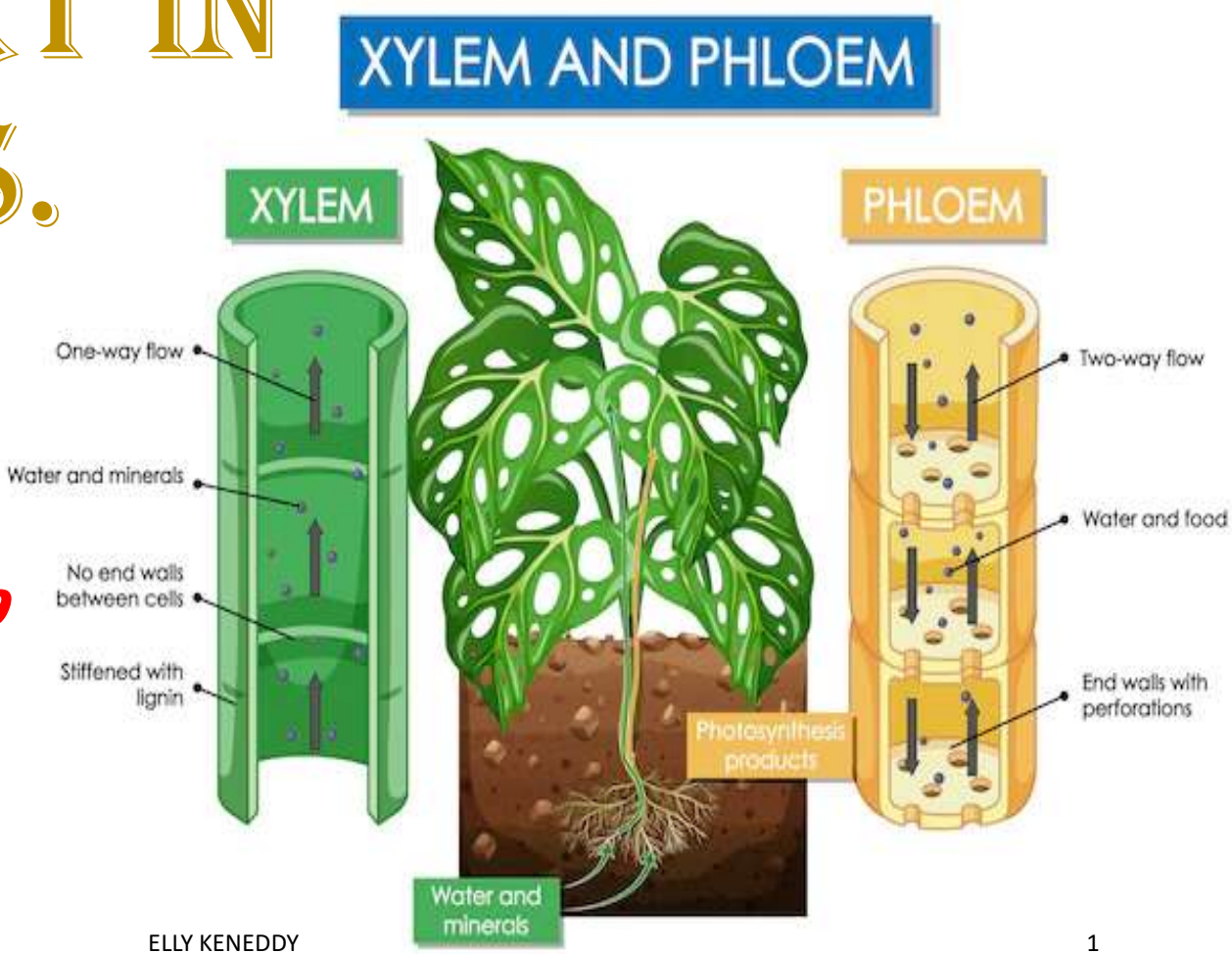


LEARNING OUTCOMES

The learner should be able to:

- understand the importance and key methods of movement of materials into and out of cells (u)
- investigate the different ways in which materials move into, though, and out of cells (s)
- know how the root hair is adopted for absorption of water and mineral salts (u)
- understand the processes of transpiration and translocation (u) conduct experiments on and understand the factors that affect transpiration (s, u

INTRODUCTION.

- **Transport** refers to the ***movement of particles (ions or molecules) from one part of an organism to another***
- Many particles are transported from one point to another using a transport network or medium.
- Organisms need to **transport materials between them selves** and **their environment** and also **within their bodies**. These materials include

MATERIALS TRANSPORTED.

- Nutrients e.g. water, glucose, mineral salts
- Waste products like urea ,water
- Respiratory gases like carbon dioxide & oxygen
- Hormones like auxins
- Heat

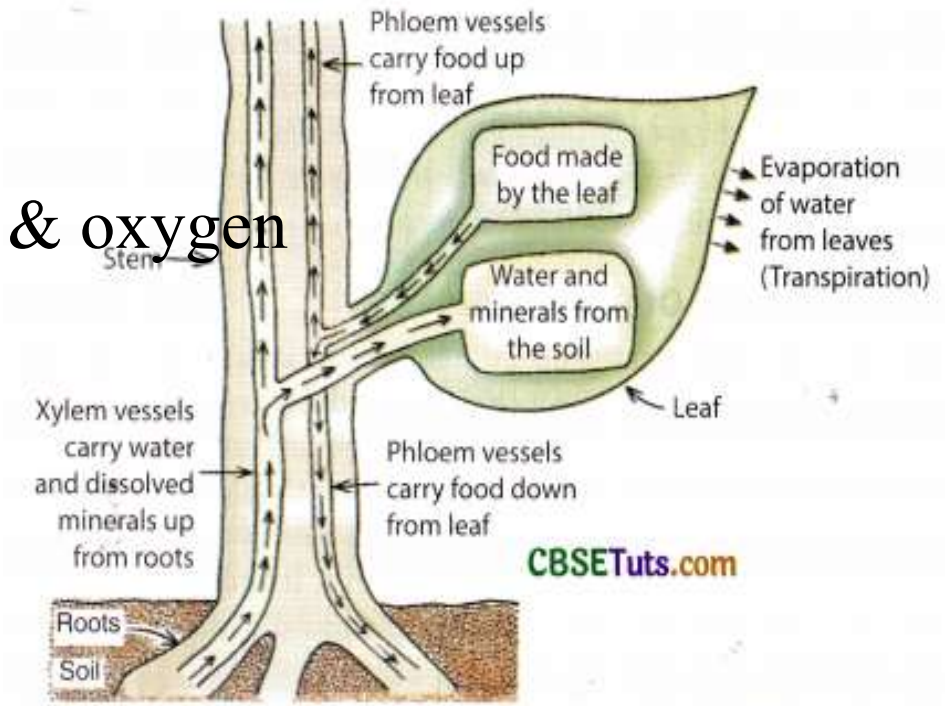


Diagram to show the transport system in plants.

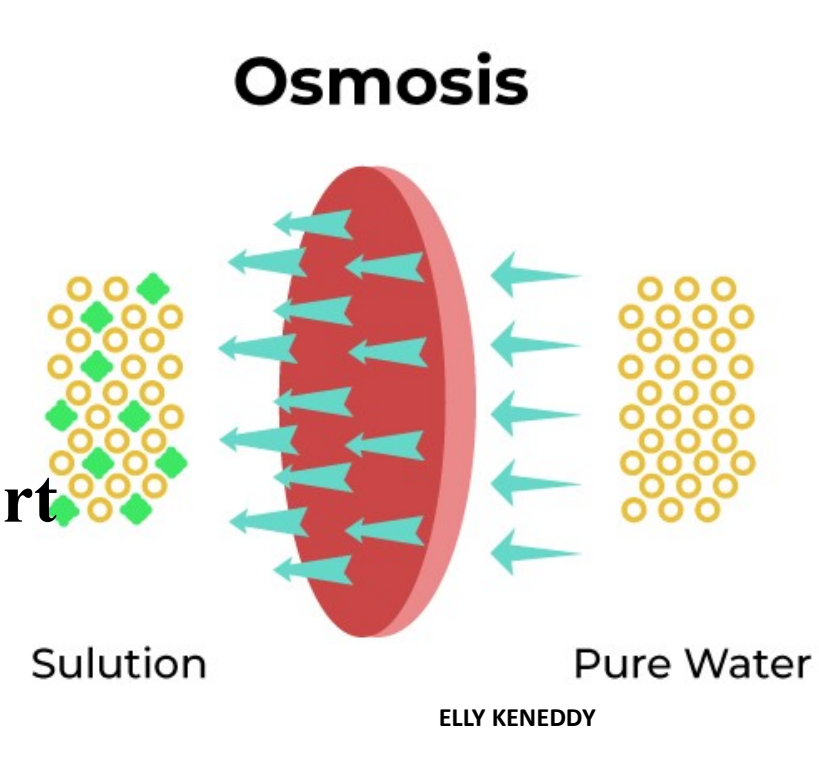
WHY PLANTS DO NOT NEED A TRANSPORT SYSTEM

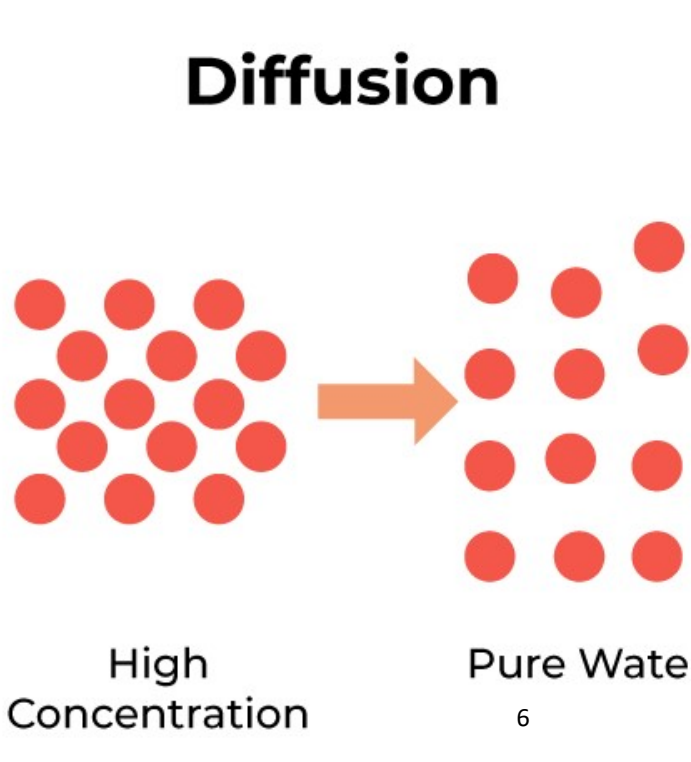
- The ***oxygen requirement of the plant is very low*** as compared to mammals.
- The ***carbon dioxide produced during respiration*** is used up during *photosynthesis*.
- Plants have a continuous series of airspaces throughout the body opening to the atmosphere by the stomata.
- In plants oxygen from the air diffuses through the stomata opening in to the airspaces and from the air spaces in to the cells by diffusion.
- And the oxygen dissolved in the soil water also diffuses through the root hairs in to the plant sap.

PROCESSES FOR MOVEMENT OF MATERIALS

In living organisms substances move in and out by **3** main processes i.e.

- ❑**Osmosis**
- ❑**Diffusion**
- ❑**Active transport**





DIFFUSION.

- The process by which ***molecules move from a region of high concentration to a region of low concentration*** along ***a concentration gradient***
- It is a passive process(doesn't use energy)

DEMONSTRATION.

FACTORS AFFECTING THE RATE OF DIFFUSION

❖Concentration gradient

Concentration gradient is the ***difference in concentration between the 2 regions where diffusion takes place***. The **higher the concentration gradient** between the two regions, **the faster is the rate of diffusion**.

❖Temperature

The ***higher the temperature of the substances*** (molecules), **the faster is the rate diffusion**, because **temperature increases the kinetic energy of molecules which move at greater speed hence diffusing faster.**

CONT……

❖Size/density of molecules

The ***smaller the molecules***, **the faster the rate of diffusion** because ***small molecules are light and can easily move than dense molecules***. The denser the particle, the lower the rate of diffusion.

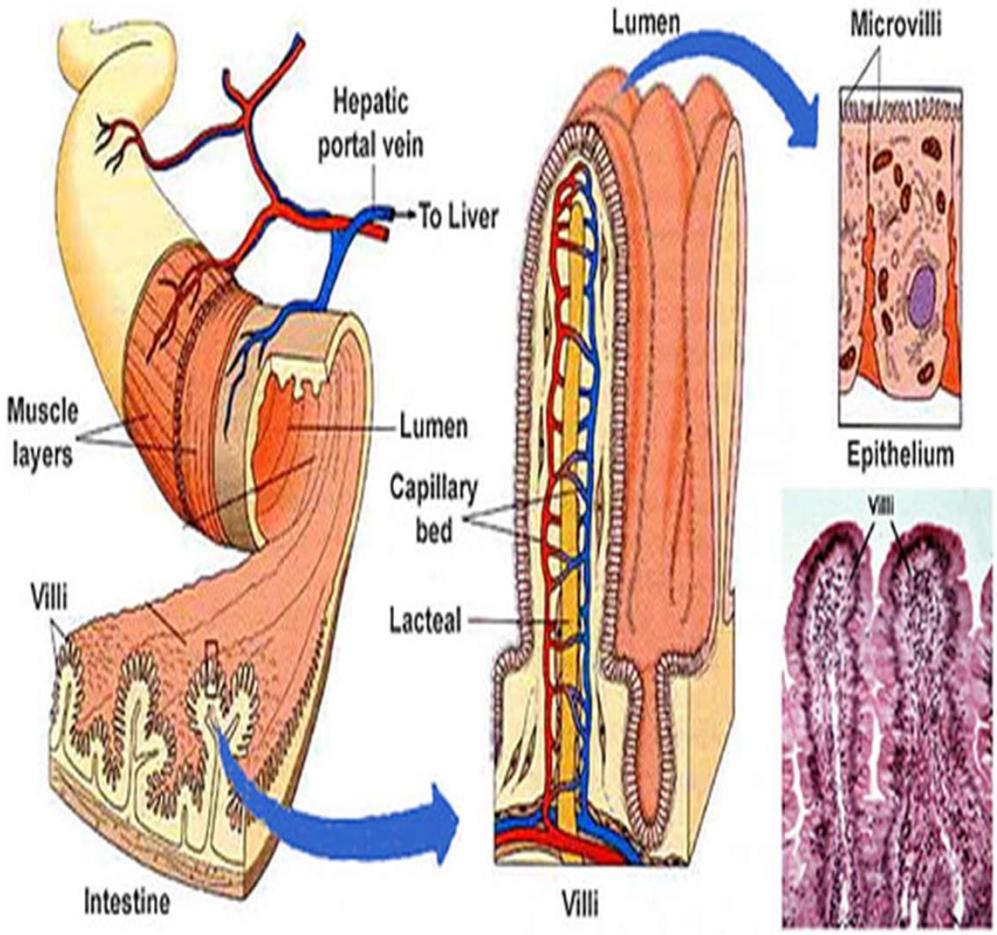
❖Distance over which diffusion occurs

The **shorter the distance** between the two regions of different concentration, **the greater is the rate of diffusion** like the alveoli of lungs or the epithelial linings of the ileum are thin to provide a short distance for diffusion thus increasing the rate of diffusion.

CONT.....

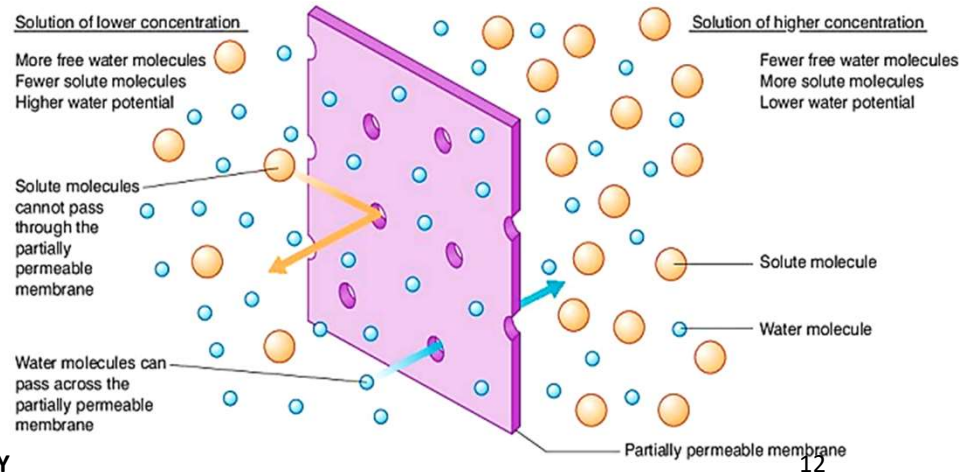
❖**Surface area over which diffusion occurs**

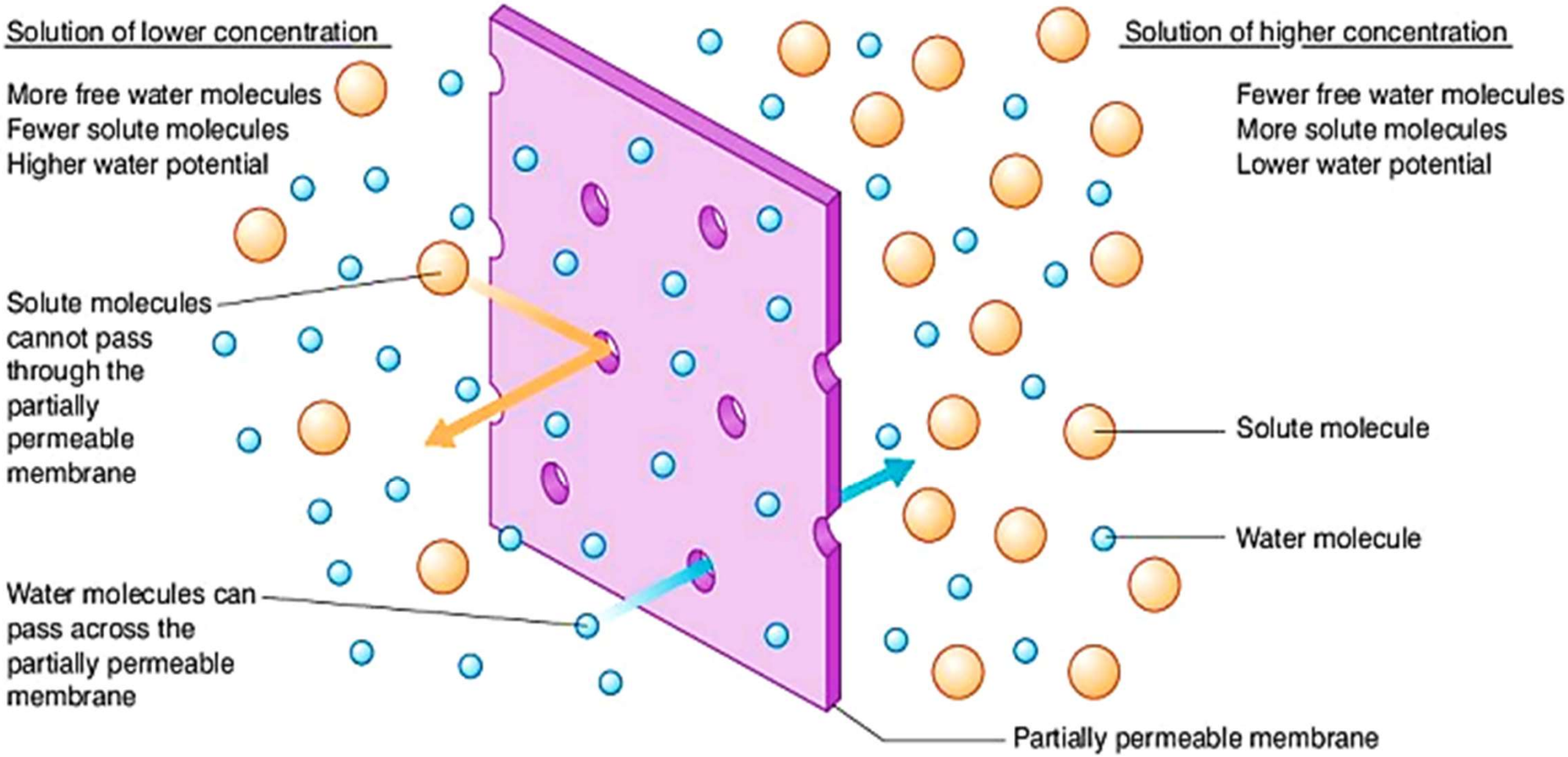
The larger the surface over which diffusion is to take place, the faster is the rate of diffusion e.g. diffusion surfaces like the ileum have numerous villi to increase the rate of diffusion



OSMOSIS.

- This is the ***movement of water/solvent molecules from a dilute solution to a concentrated solution*** across a ***semi permeable membrane***. **or**
- It is the ***movement water/solvent molecules from a solution of low solute concentration*** to a ***solution of high solute concentration*** across **a semi permeable membrane.**
- A semi/partially/selectively permeable membrane is one which can allow the **passage of some materials to occur** and **prevent other materials** from passing across it




Solution of lower concentration
More free water molecules
Fewer solute molecules
Higher water potential
Solution of higher concentration
Fewer free water molecules
More solute molecules
Lower water potential
Solute molecules cannot pass through the partially permeable membrane
Solute molecule
Water molecule
Water molecules can pass across the partially permeable membrane
Partially permeable membrane

TERMS USED IN OSMOSIS

- **Hypotonic solutions** :This is used to describe a solution containing less solute and more water molecules compared to another e.g. hypotonic solution has a lower osmotic pressure and is generally termed as less concentrated.
- **Isotonic solutions** : These are solutions with the same concentration of salts and water i.e. Solutions with the same isotonic pressure
- **Hypertonic solutions** : This is used to describe a solution with more solutes and less water molecules than the other. A hypertonic solution has a higher osmotic pressure and is generally termed as more concentrated solution.

OTHER TERMS USED IN OSMOSIS

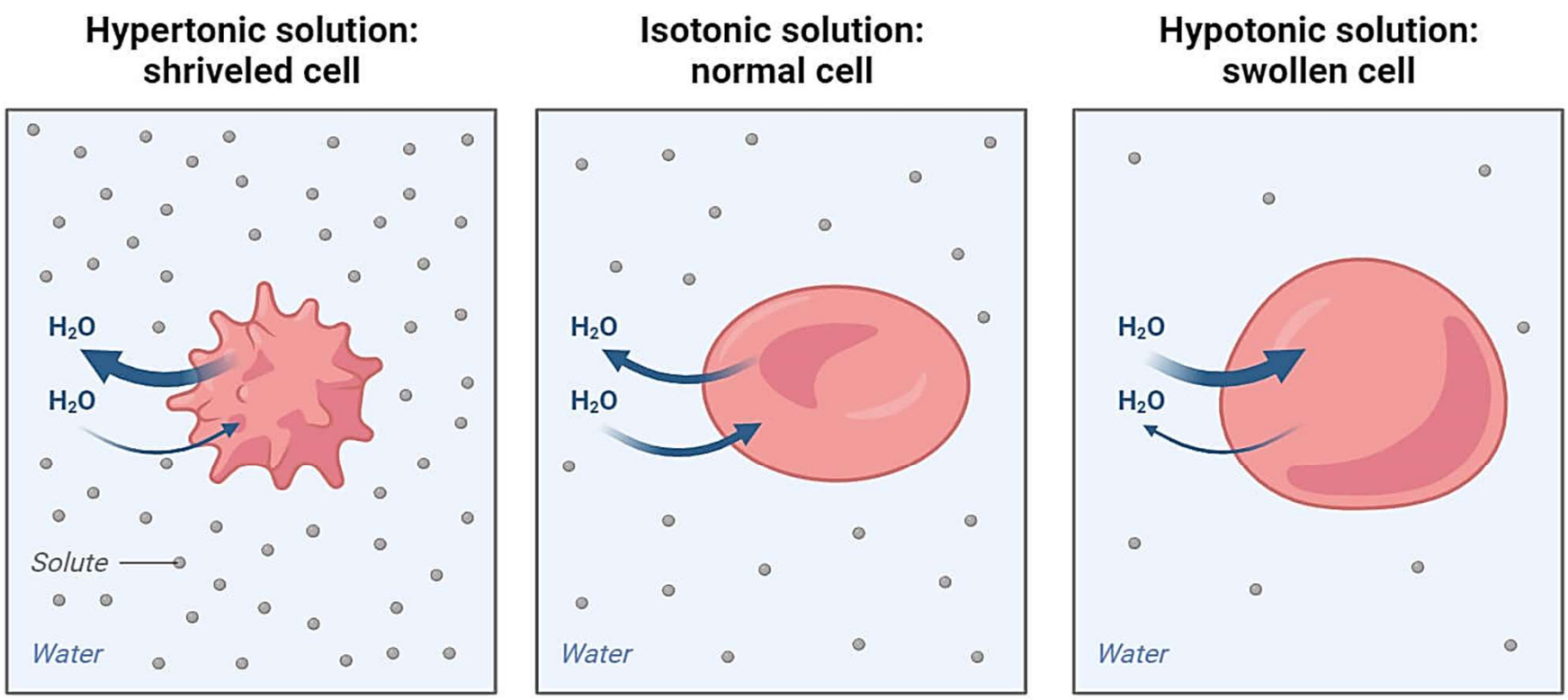
- **Osmotic potential** :This is the ability of a solution to exert osmotic pressure. This describes the concentration of the solution of the solution in terms of the ability of water molecules to move hence a solution with high osmotic potential has more water molecules able to move.
- **Water potential** :This is the concentration of water in a solution. Therefore a solution has a high osmotic pressure if it is highly concentrated and vice versa. This is the ability of a hypotonic solution to loose water to a more concentrated solution.

OSMOSIS AND CELLS

Osmosis and red blood cells

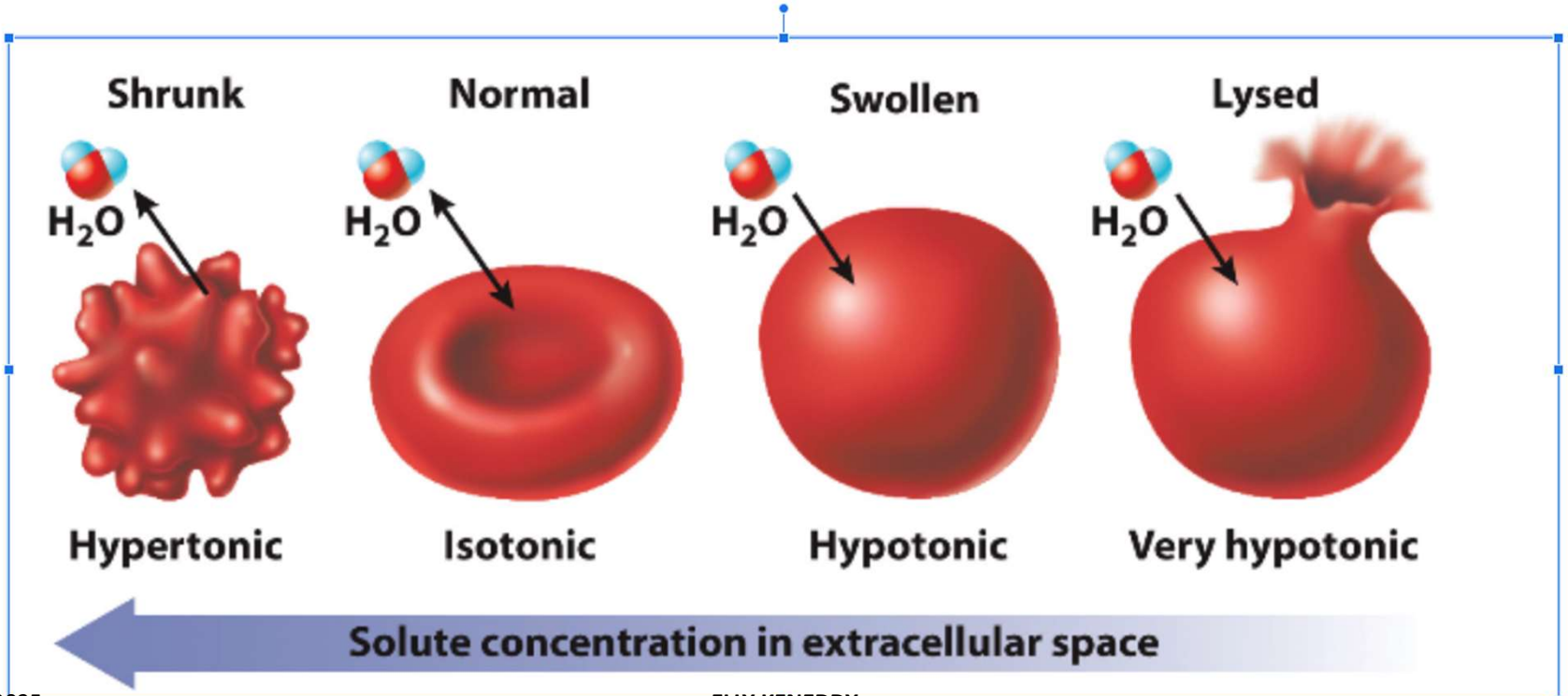
- When red blood cells are placed in a dilute solution (hypotonic solution) i.e. distilled water, ***the cells swell up and eventually burst (haemolyse*)*.***
- This is because ***water moves from the surrounding solution (distilled water) via the semi permeable cell membrane into cells by osmosis.***
- Animal cells unlike the plant cells, **animal cells lack a cell wall** and **only have a cell membrane** which is **weak and non-resistant to high internal pressure**.
- When the red blood cells are placed in a more concentrated solution (hypotonic solution) e.g. a strong sugar solution, ***water moves out of the cells to the surrounding solution by osmosis.***
- As a result, **the cells shrink the process called crenation or laking**.

NB. When red blood cells are placed in **isotonic solution** they **neither gain nor lose water.**

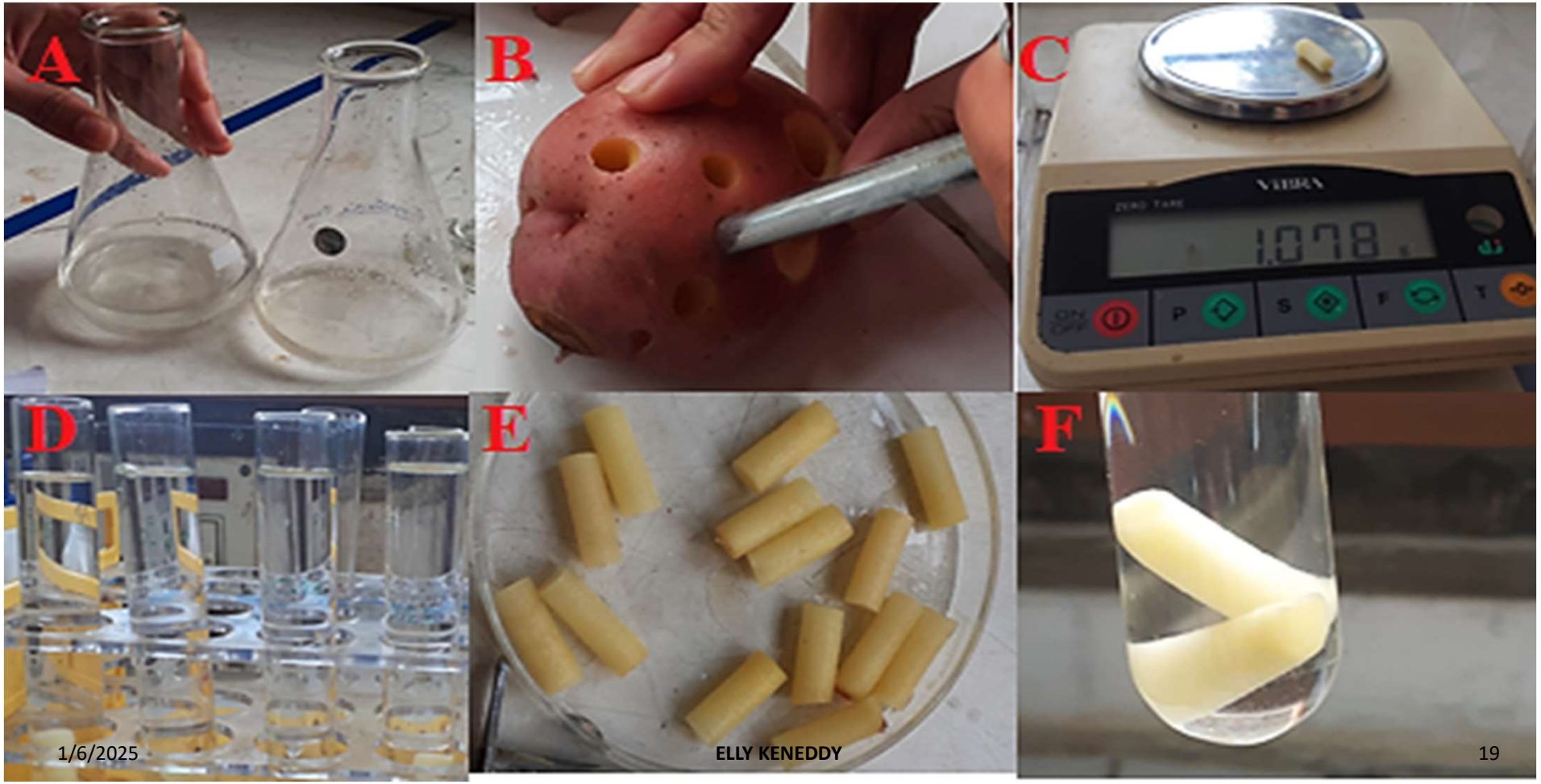

Hypertonic solution:
shriveled cell
Isotonic solution:
normal cell
Hypotonic solution:
swollen cell
H2O
H2O
Solute
Water
H2O
H2O
Water
H2O
H2O
Water

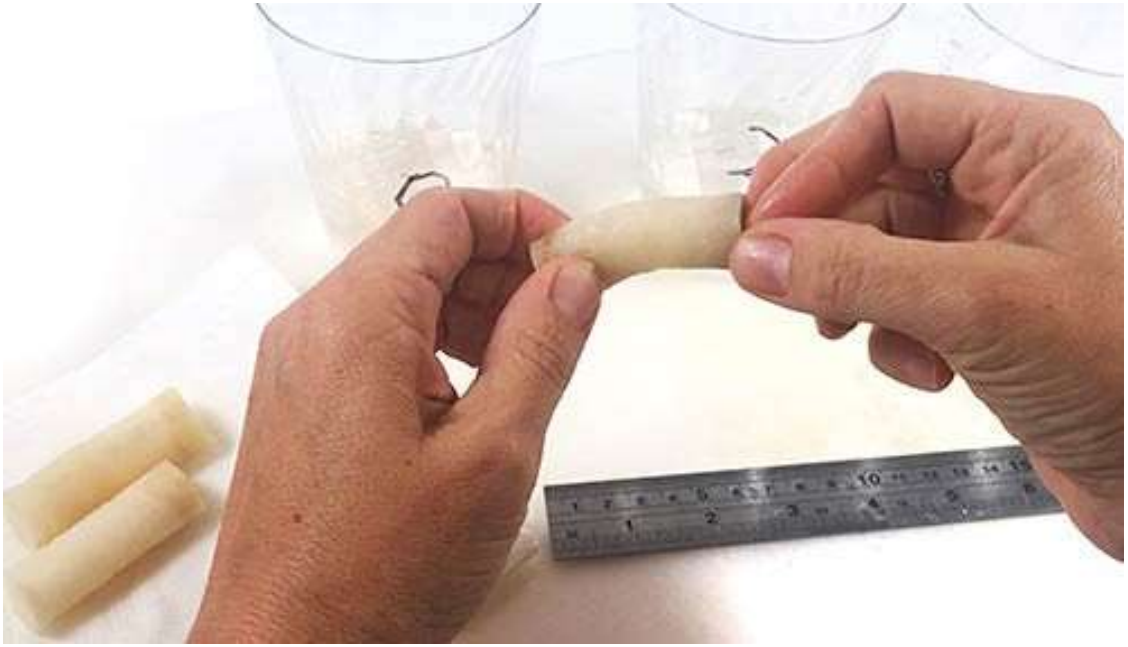
HEMOLYSIS IN RED BLOOD CELLS

Which type of cell is optimal for animal cells? For plant cells?



OSMOSIS IN POTATO TISSUES.



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PROCEDURE

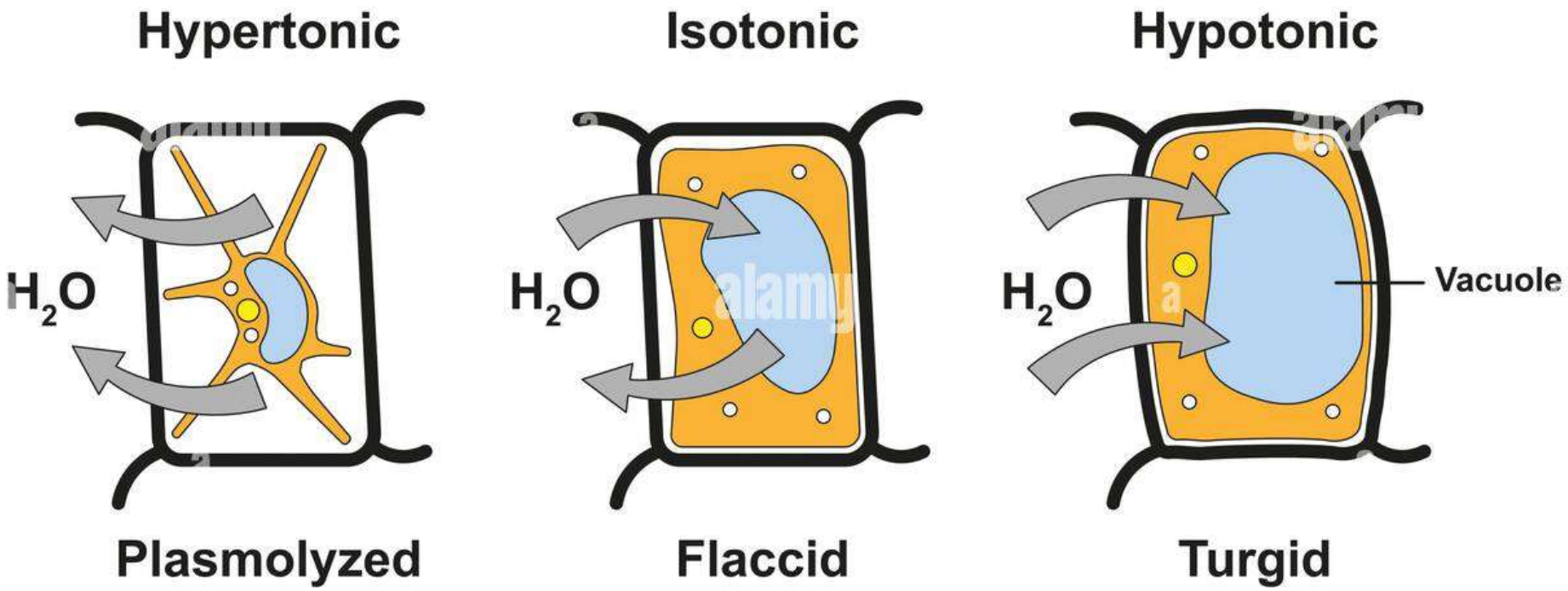
- ***Using the pictures above and text books, identify the materials used and generate the procedure to be followed.***

RESULTS(SAMPLE)

Initial length/cm	Final length/cm	Change in length/cm	% change in length	Texture
4.0	4.3	+0.3	+7.5	Tough , rough
4.0	4.0	0	0	Tough , rough
4.0	3.8	-0.2	-5	Soft/flaccid , smooth
4.0	3.9	-0.1	-4	Soft , smooth

EXPLANATIONS

- The cylinder in dilute solution ***increased in length***, ***became rough and stiff*** because **water molecules moved into it from the surrounding water by osmosis making the cells turgid**.
- This is because ***the cell sap had a higher solute concentration*** than the surrounding water.
- There was ***no change in length for the cylinder in 5% sucrose solution*** because the **solution had the same concentration as the cell sap of a potato** cylinder hence **no net osmosis occurred**.



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- There was ***a decrease in length for the cylinder in 50% sucrose solution*** because **water molecules moved out of the cylinder by osmosis** which **had a lower concentration of water molecules.**
- There was ***a decrease in length for the cylinder*** in the empty beaker because **water was lost to the surrounding through evaporation.**

Conclusion

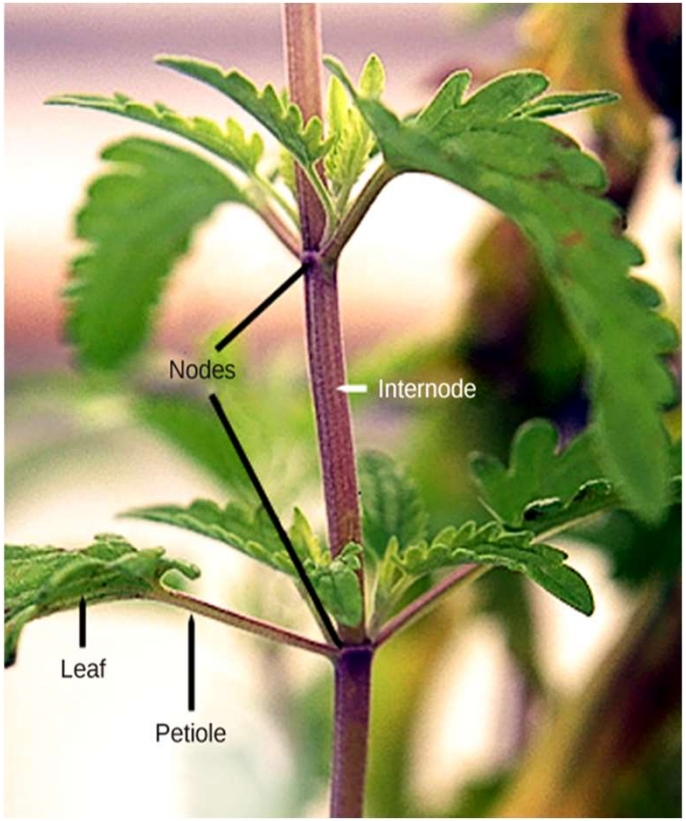
- High solute concentration leads to loss of water by osmosis
- Low solute concentration leads to gain of water by osmosis in the plant tissues.

NOTE.

- ✓**Turgor** This is the attainment of enough water in the cell to make it expand to its maximum volume.
- ✓**Turgor pressure** This is the force exerted on the cell wall of the plant cell due to pushing of the cytoplasm as a result of water entering the cell vacuole and expanding.
- ✓**Turgidity** Is a state of a cell which has attained enough water and expanded to maximum size.
- When ***a plant cell is placed in a dilute solution*** (water) than the cell sap, **water enters by osmosis through the semi permeable cell wall and cell membrane** into the cell sap. The **volume of cell sap increases and it makes the sap vacuole expand**. This causes the **cytoplasm move towards the cell wall and gaining turgidity**.
- Time comes when all the cytoplasm is pressing against the cell wall and no more water can be absorbed. At this state, the cell is said to have gained full turgidity.

SIGNIFICANCE OF OSMOSIS IN PLANTS

- Absorption of water by root hairs from soil
- It enhances movement of water from root hairs via the cortex to the xylem.
- Enhances support in non- woody plants
- It facilitates opening and closing of stomata
- In germination, the initial absorption of water is by osmosis

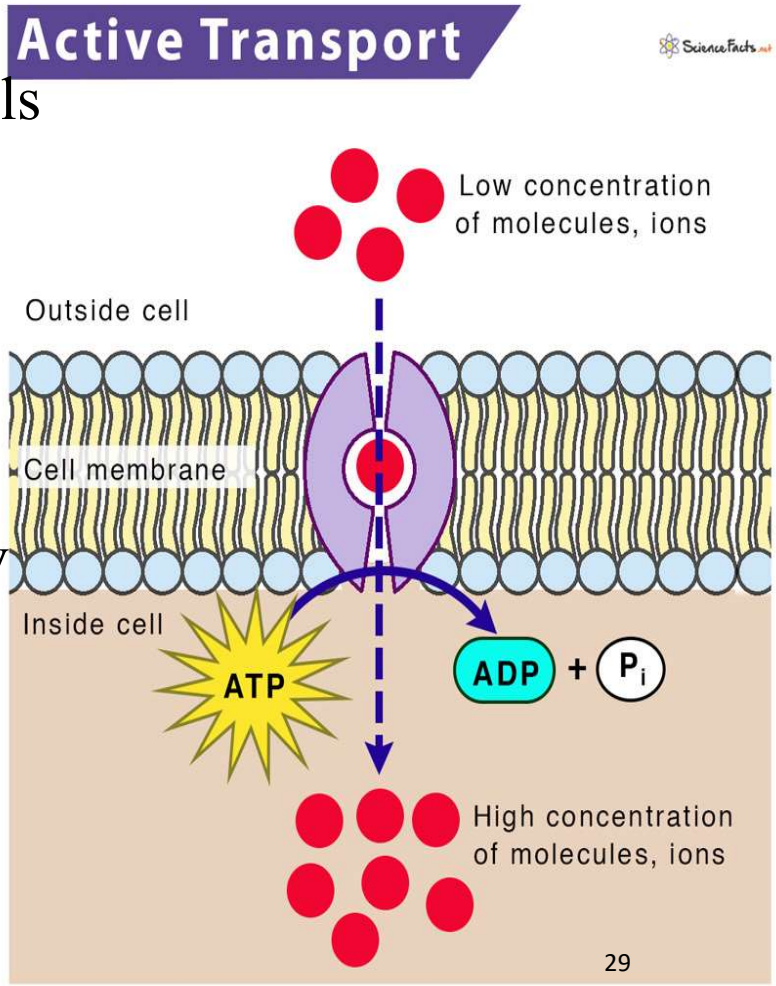


ACTIVE TRANSPORT

- This is the movement of molecules from the region of low concentration to the region of higher concentration i.e. movement against concentration gradient using energy.
- Energy for this process is derived from respiration. Anything that affects the rate of respiration, also affects the active transport e.g. cyanides prevent ATP synthesis.
- Active transport takes place by means of carrier molecules in the cell membranes which are protein.
- The carrier, on reaching the inner part of the membrane releases the molecules and is set free for further transportation.

IMPORTANCE OF ACTIVE TRANSPORT

- Used by plant roots or root hairs to absorb minerals from the soil.
- Used in the absorption of food materials from the ileum into the blood stream
- Used in the reabsorption of minerals in the kidney during urine formation
- Used in the secretion and active uptake of ions in the fish gills from fresh water



EXAMPLES OF ACTIVE TRANSPORT

- Up take of mineral salts from soil by plant roots from soil where are less concentrated to where they are more concentrated
- Absorption of some food molecules e.g. glucose
- Selective re absorption of molecules e.g. glucose
- Plants growing in salty water take in salts by active transport

TRANSPORT IN PLANTS

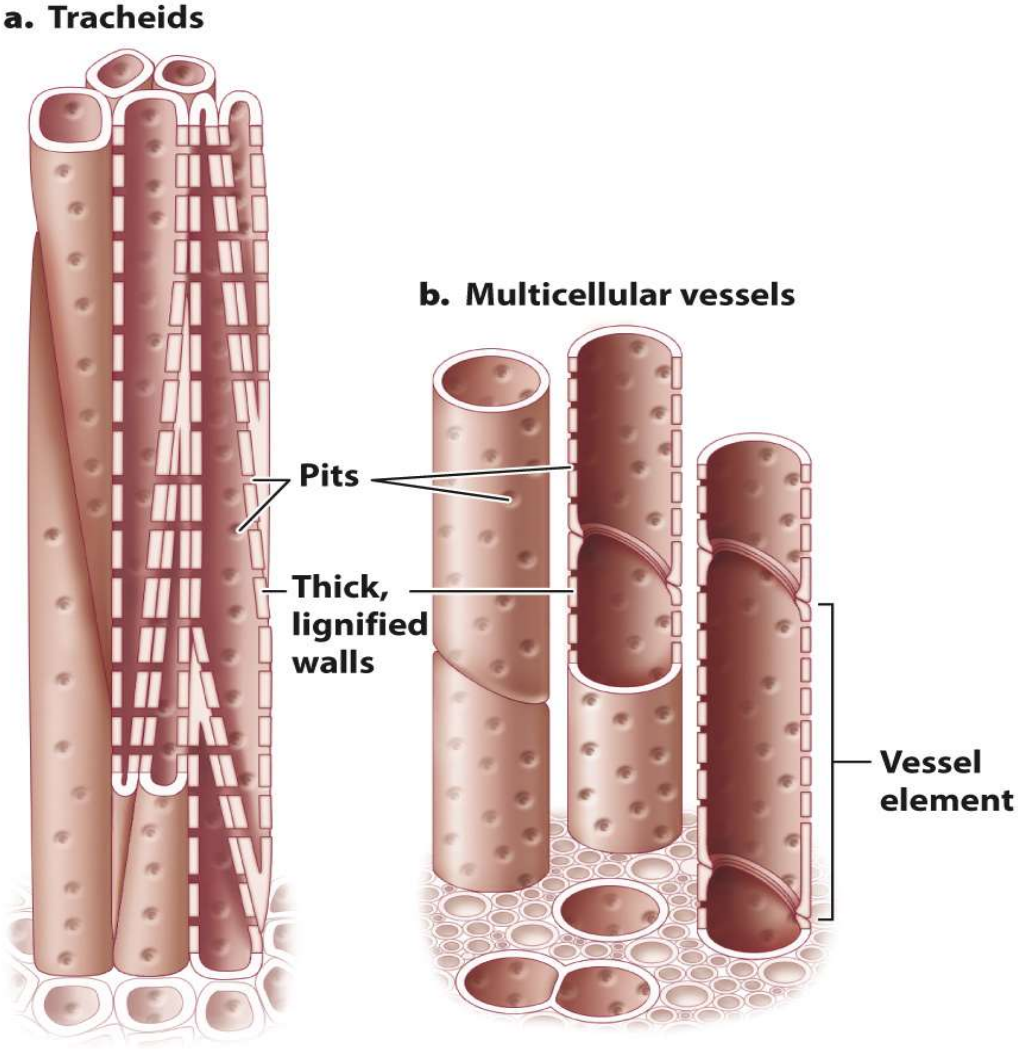
Transporting tissue in plant **is xylem** and **phloem**. Transport involves movement of water, salts and organic molecules (manufactured food) to parts where they are required.

THE XYLEM

- This Consists of xylem vessels and tracheids.
- Xylem vessels develop from cylindrical cells, arranged end to end, in which the cytoplasm die and cross- walls disappear leaving a dead empty tube.
- Through this, water, mineral salts, move from roots, stems, up to leaves.
- Xylem vessels are strengthened by lignin in their walls. This strength gives support to the soft tissue of roots, stems, and leaves: it also prevents collapse of the vessels under tension as sap pressure changes.

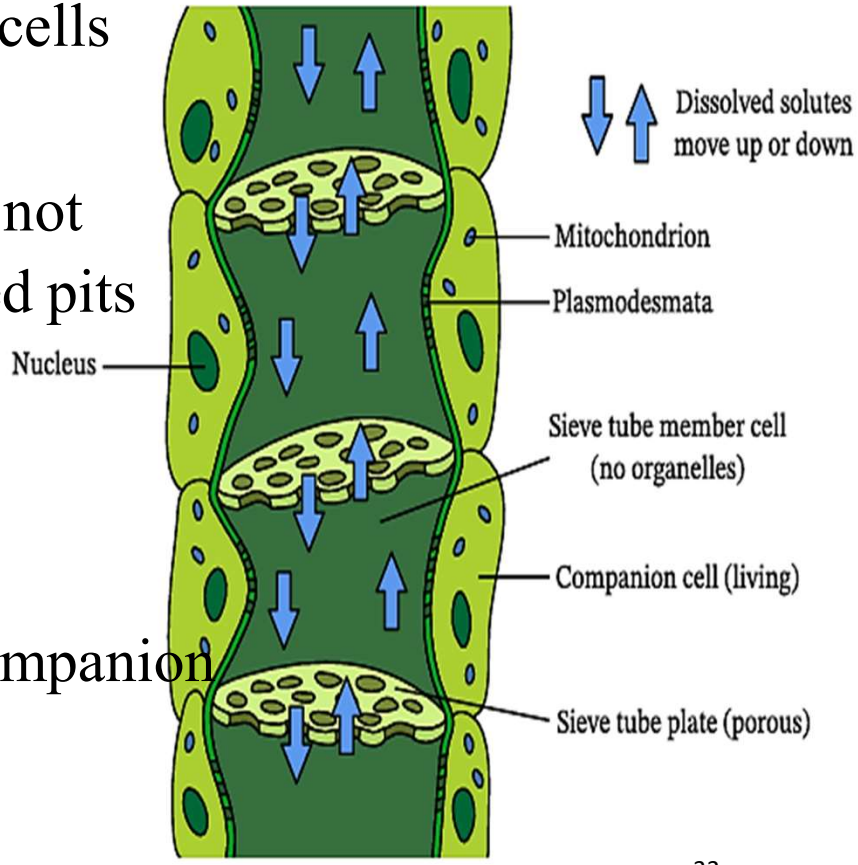
CHARACTERISTICS OF XYLEM TUBES

- Consist of dead cells
- They are hollow
- Its walls are lignified
- Has no protein filaments
- Has no cytoplasm
- Transports water and salts from roots to the shoot.



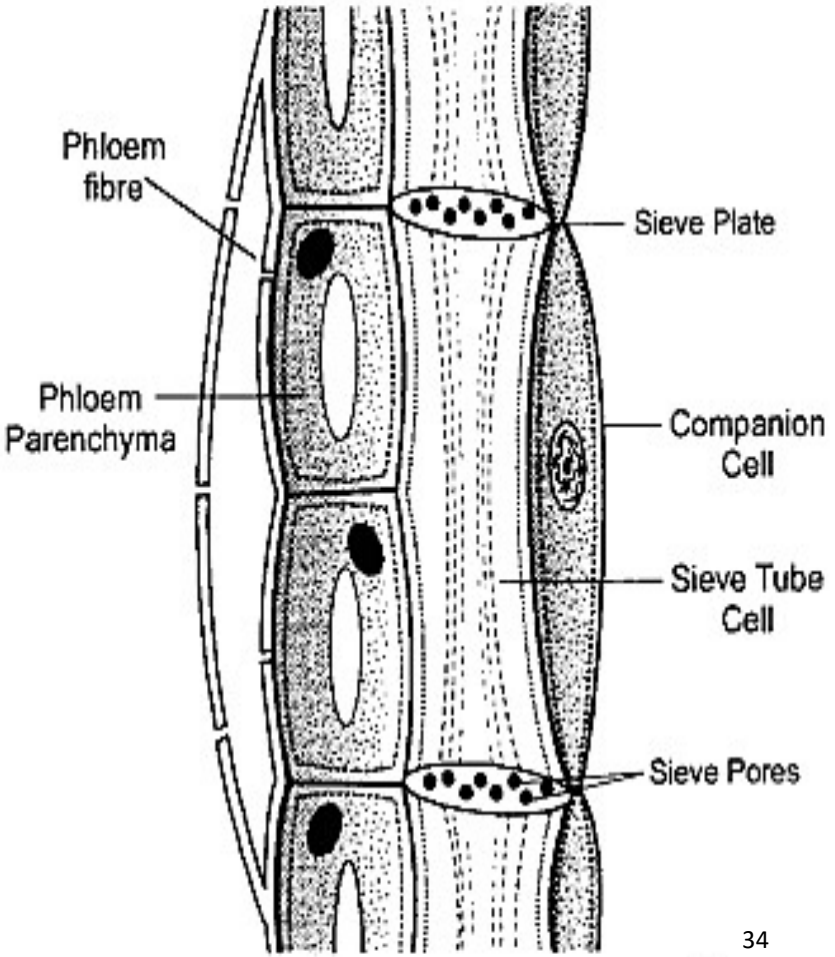
PHLOEM TISSUE

- This Consists of sieve tubes and companion cells.
- The sieve tubes are formed from cylindrical cells arranged end to end.
- Unlike the xylem vessels, the cross walls do not disappear but develop perforations of enlarged pits forming sieve plates.
- The cell remains living; although its nucleus disintegrates as the cell differentiates.
- Each sieve tube is closely associated with companion cells which are complete cells.



CHARACTERISTICS OF PHLOEM TISSUE/TUBE

- ❖Consist of living cells
- ❖Have a thin cytoplasm
- ❖Associated with companion cells
- ❖Consist of sieve cross walls
- ❖Consist of protein filaments
- ❖Transport food materials



COMPARISON

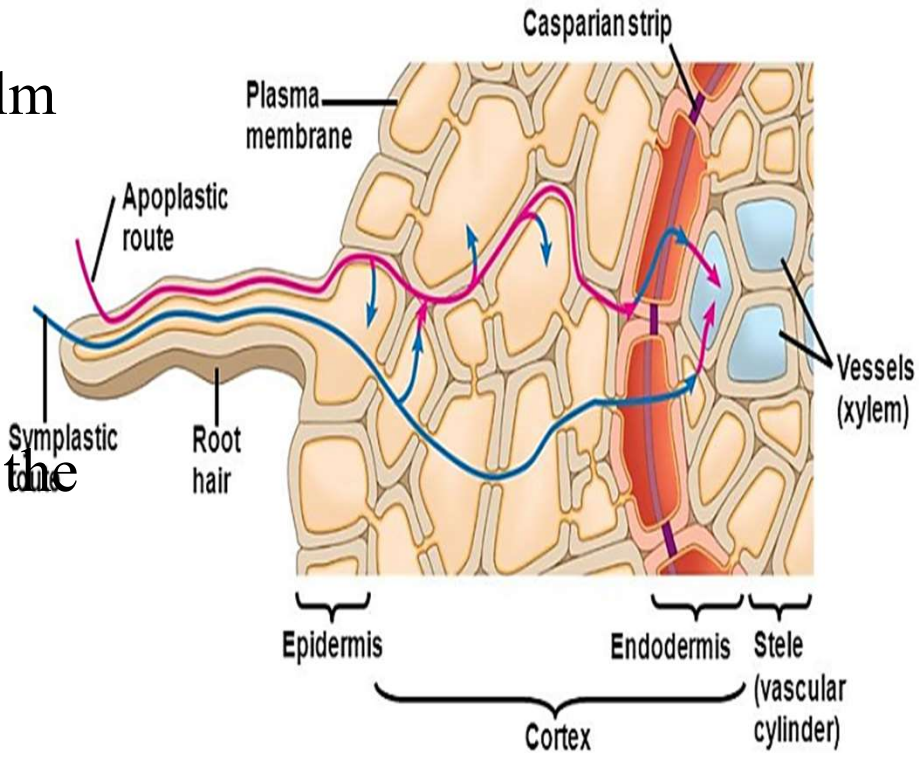
Similarities

- Both have cells without nucleus e.g. vessels and tracheids in xylem and sieve tubes in phloem.
- Both are perforated, i.e. xylem is bordered with pits and phloem has sieve pores in the sieve plates
- Both tissues are surrounded by parenchyma cells as packing tissues

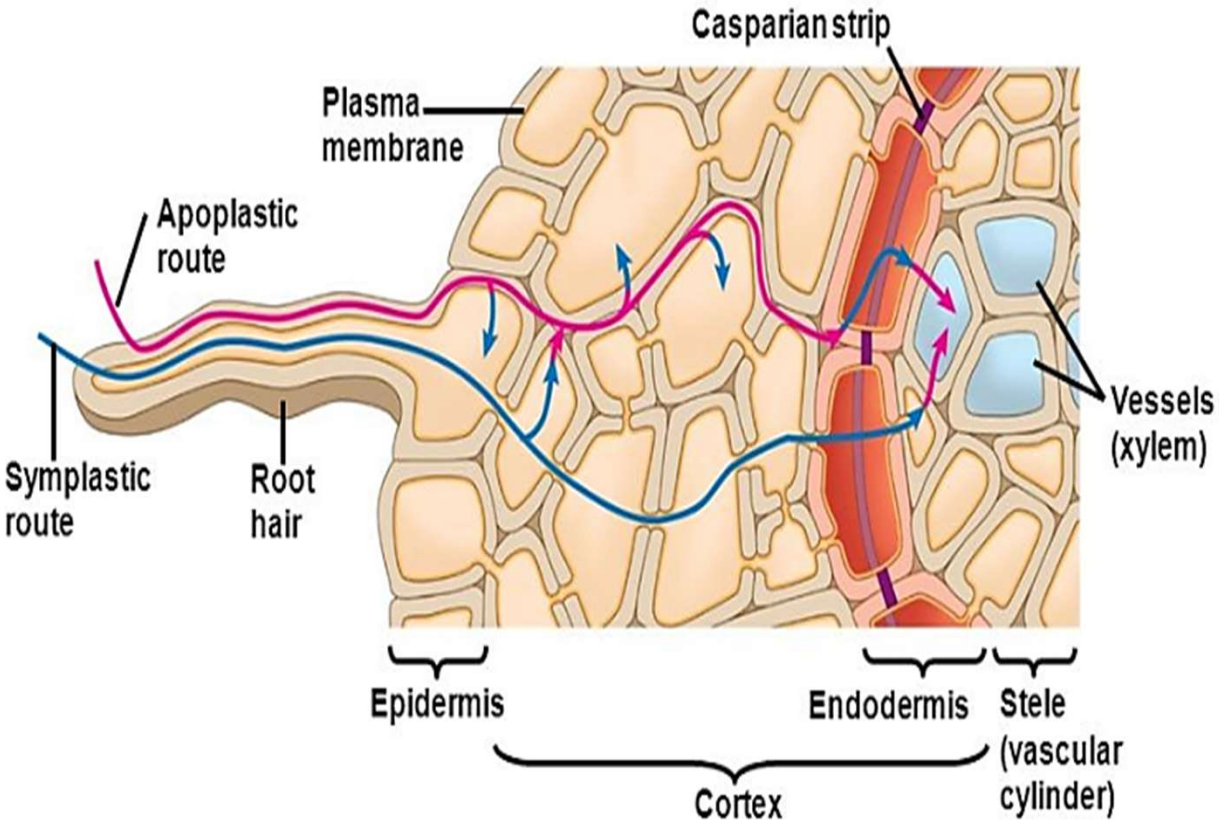
Xylem	Phloem
Consists of dead cell walls xylem and phloem	Consists of living cells
Vessels are lignified	They are non- lignified
Consists of open ended vessels and tapering tracheids	Consists of sieve tubes with sieve plates and cytoplasmic strands
Transports water and mineral salts	Transports manufactured food
Transportation depends on transpiration pull	Depends on respiratory energy

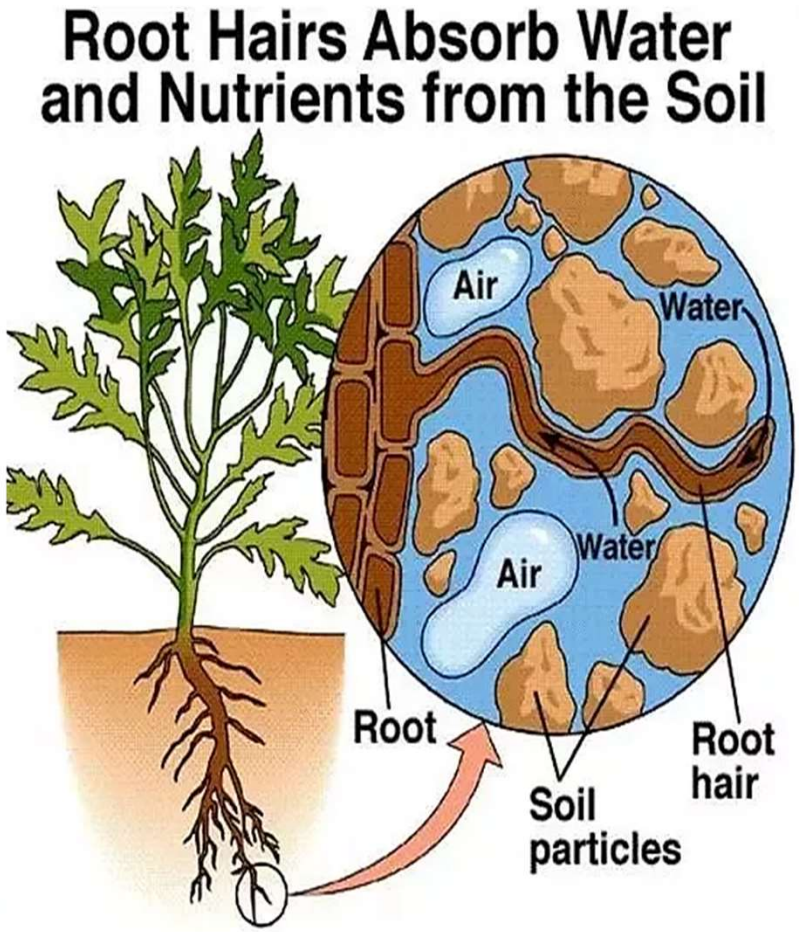
TRANSPORT OF WATER FROM SOIL TO THE LEAVES

- Up take of water also called absorption is a continuous stream through the plant.
- Root hairs in the soil are surrounded by a film of water containing mineral salts/ soil solution.
- The soil solution once inside the root hair vacuole is called cell sap and is a strong solution than the soil solution(has a lower osmotic potential and the cell membrane of the root hair is semi permeable.
- The above conditions enable water to move from the soil, passes through the cell membrane in to the vacuole by osmosis.



MECHANISM OF WATER ABSORPTION





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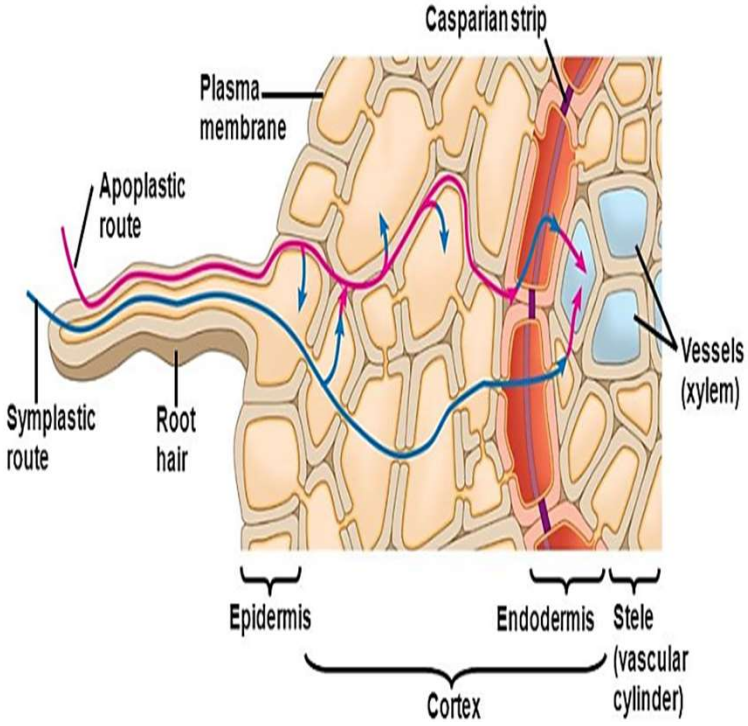
- Addition of water to the root hair all which is absorbed by osmosis makes it to attain higher osmotic potential as compared to the neighboring cells with stronger cell sap.
- This enables water to move to and from the root hair to other cells of the cortex and through the cortex cells until it reaches the xylem which conducts water up the plant.
- The water rises up the xylem by the following forces.



❑Capillarity

- This is the ability of water to move up the fine tube.
- It is usually caused by the surface tension but because the capillary tube is narrow, the water rise is limited.

❑Cohesion – tension forces

- This is a force of attraction between the molecules of the same substance. Cohesion between water molecules allows water in a continuous column without breaking.
- This occurs because as water is lost by transpiration from the leaves, the water potential at the top of xylem vessels falls below that at the bottom of the xylem in the root.

Note

Water is now pulled by this potential difference because of the cohesion of the water molecules.

Adhesion

- This is the force of attraction between molecules of different substances.
- Adhesion forces between walls of xylem and water molecules support a considerable weight of water within the xylem tissue and prevent the water in the xylem vessels from collapsing.

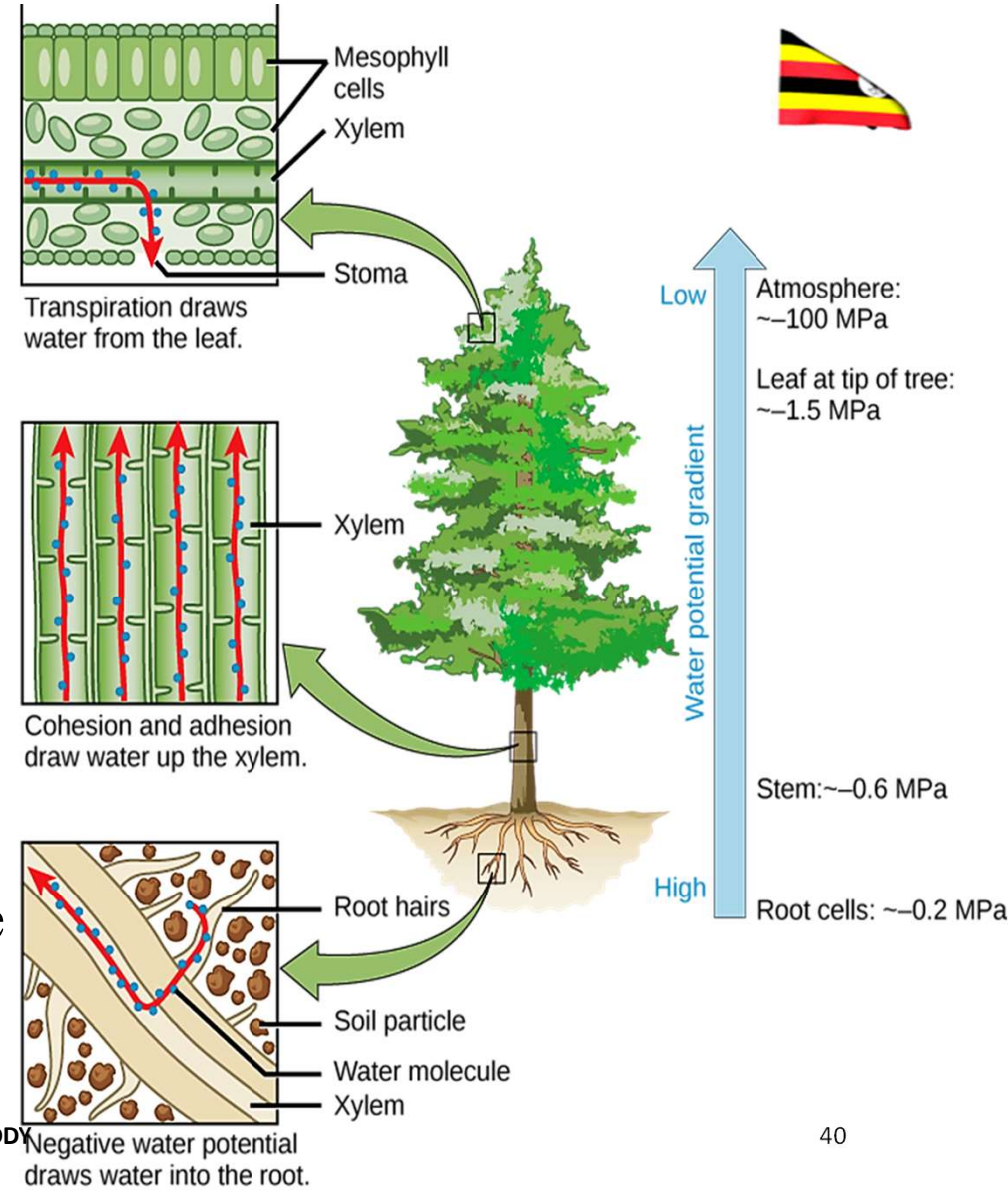
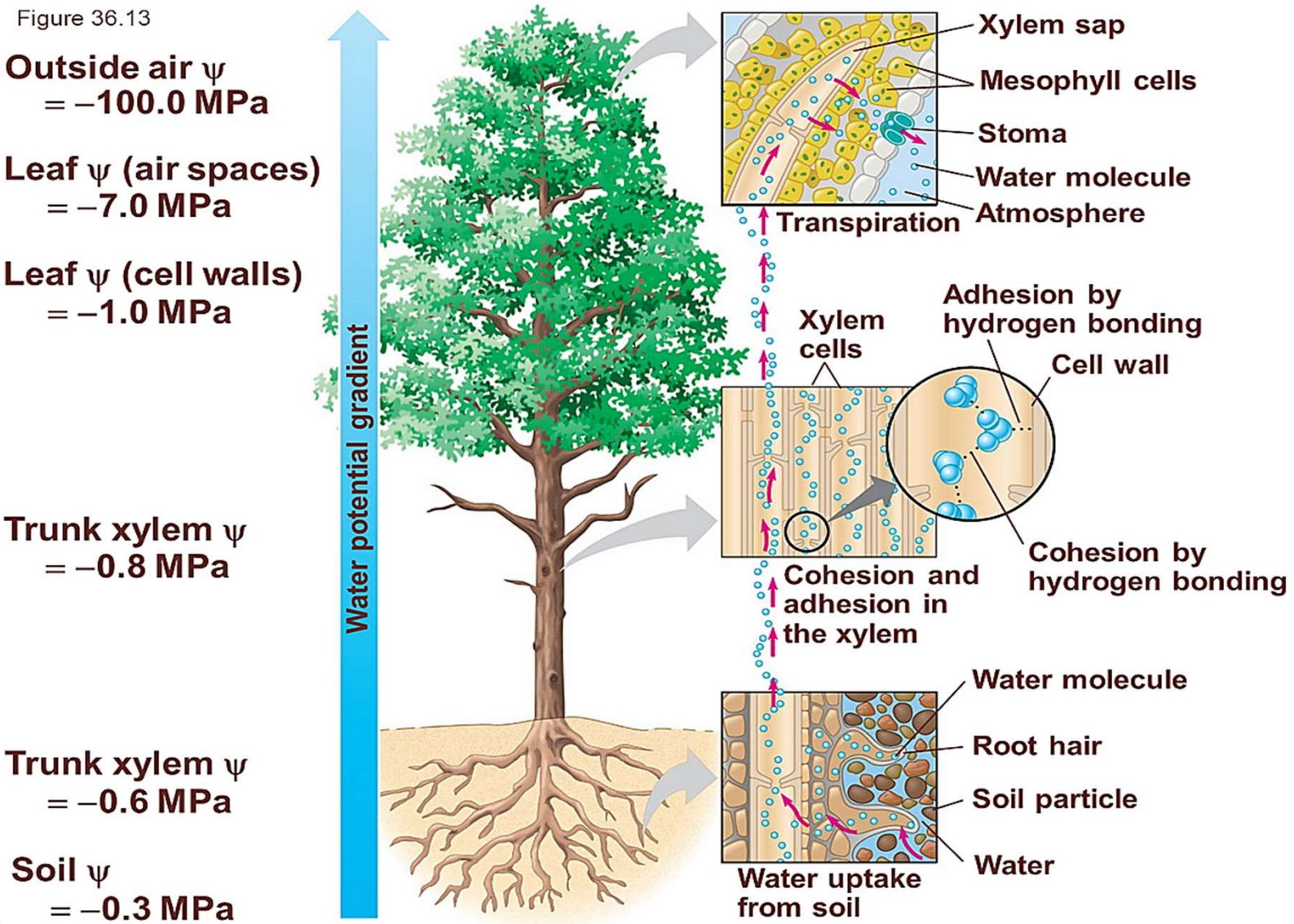


Figure 36.13



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ROOT PRESSURE

- This is regarded as the **pressuring force of the water up the stem from the roots.**
- The root pressure theory has been ***suggested as a result of a common observation that water tends to exude from the cut stem*** **indicating that some pressure in a root is actually pushing the water up**.
- However, like capillary, root pressure is not sufficient on its own to push water to the leaves of the plant at the top of the tree and can slowly cause guttation in transpiring herbaceous plants.

ADAPTATIONS OF THE ROOT HAIR TO WATER ABSORPTION

- The root hair is slender and flexible and can therefore fit between the soils particles.
- They are numerous which increase the surface area available for water absorption.
- They lack the cuticle which would restrict water absorption.
- They are long and narrow which increases surface area to volume ratio that increases the rate of water absorption.
- The cytoplasm of the root hair contains numerous mitochondria where respiration occurs to release energy needed for active absorption of mineral salts from the soil
- The cell sap of the root hair contains sugars, amino acids and salts, and so its concentrated than the soil solution and this low osmotic potential enables water to entre it by osmosis

IMPORTANCE OF WATER TO THE PLANT

Raw material for photosynthesis

- Solvent for mineral salts and oxygen that enable them to diffuse into the roots.
- It is a constituent of the cytoplasm and all sap of the growing plants
- Provides turgidity which provides support in non woody plants
- Cools the leaves of the plants during transpiration

Absorption of mineral salts by the root hairs

- Mineral salts are moved in the plant in the xylem in solution with water. Roots absorb mineral salts in form of ions by
- diffusion and active transport. Active transport is the movement of the materials against the concentration gradient by

TRANSPORT OF THE PRODUCTS OF PHOTOSYNTHESIS

- The process by which the soluble products of photosynthesis are carried in plants is called ***translocation.***
- Translocation is the movement of manufactured food from the side of photosynthesis.
- Throughout the plant, sugars and amino acids are transported in the phloem from the leaves to the growing parts of the plant or storage organs.
- Food substances may also move from the storage organs to the growing regions of the plants.
- In the phloem, food substances may move upwards/down wards

THE PROCESS OF TRANSLOCATION PROCESS

- The process of photosynthesis leads to accumulation of food substances in leaves.
- This causes a high turgor pressure within the leaves.
- Food substances in the roots are used for respiration or they are stored in the storage organs and these results in the low turgor pressure in the root cells.
- The difference between turgor pressure in the roots and leaves enables the food substances to move from leaves to other parts of the plant by a process called **mass flow** which is the major **process of translocation**.
- There is also a minor process i.e. ***active transport where the sugars*** e.g. sucrose are actively transported from leaves to the storage organs

EVIDENCE TO SHOW THAT FOOD MADE IN LEAVES IS TRANSLOCATED BY THE PHLOEM

The Ring Experiment

- Remove a ring of the bark from the stem at a point between the ground and the upper leaves.
- Leave another plant with the ring on. The plants are left to stand for one week after which the observation is made.

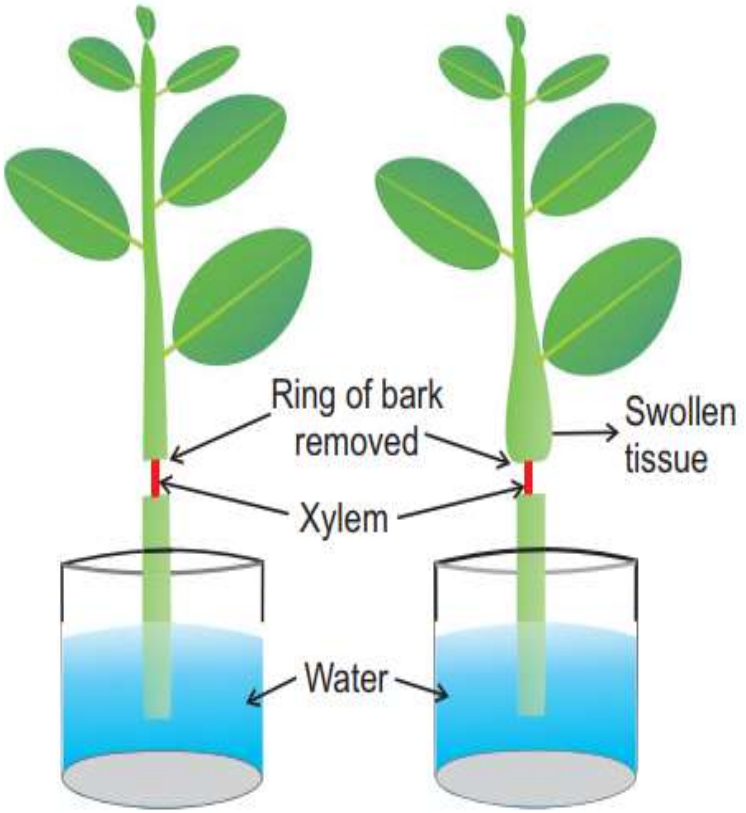


Figure 11.20: Ringing experiment

Observation

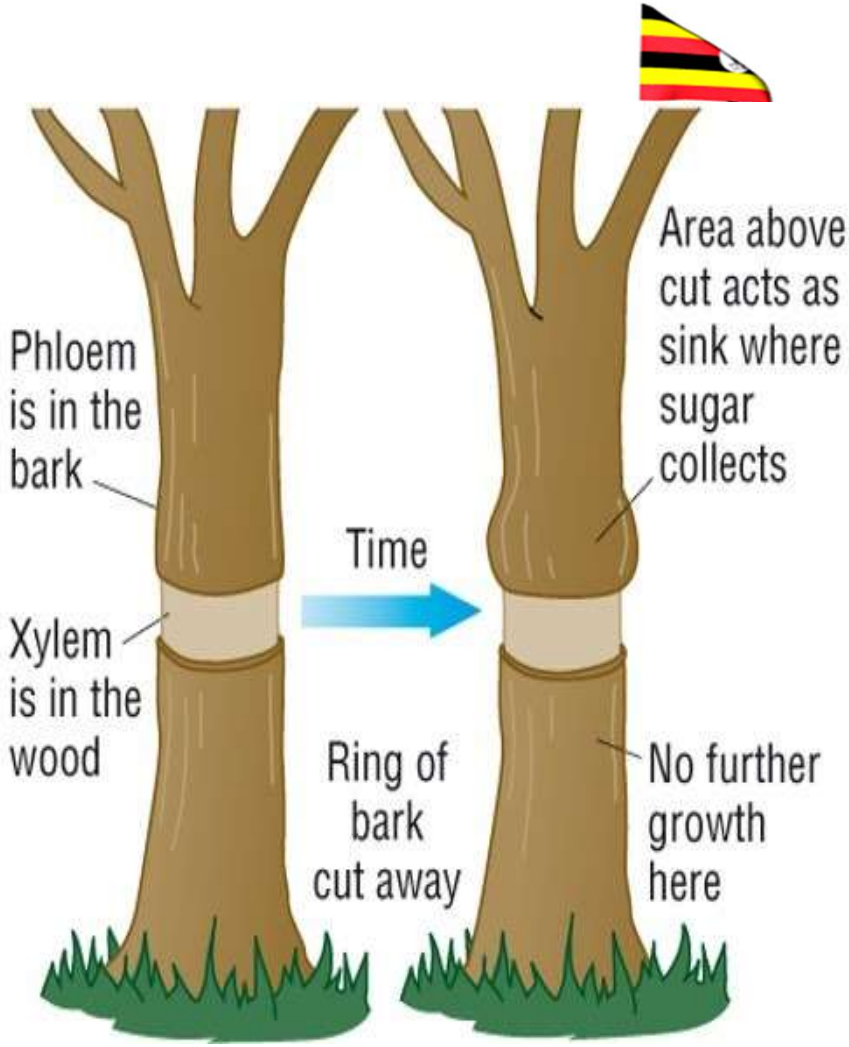
- The upper part of the stem of the ring plant swells immediately above the ring while the lower part of the stem remains unswollen.
- The un-ringed plant remains unchanged.

Conclusion

- The phloem transports manufactured food.

Explanation

- When a ring of a base is cut, the phloem tissue is removed along with it since it's found within the bark.
- This cuts off the supply of manufactured food to the lower parts of the plant.
- The food will then accumulate in the upper part hence it will swell.
- When the ring is removed, the plant also dries because the food supply to the root is cut off therefore the stored food in the roots gets exhausted then the roots die.



Feeding Aphids

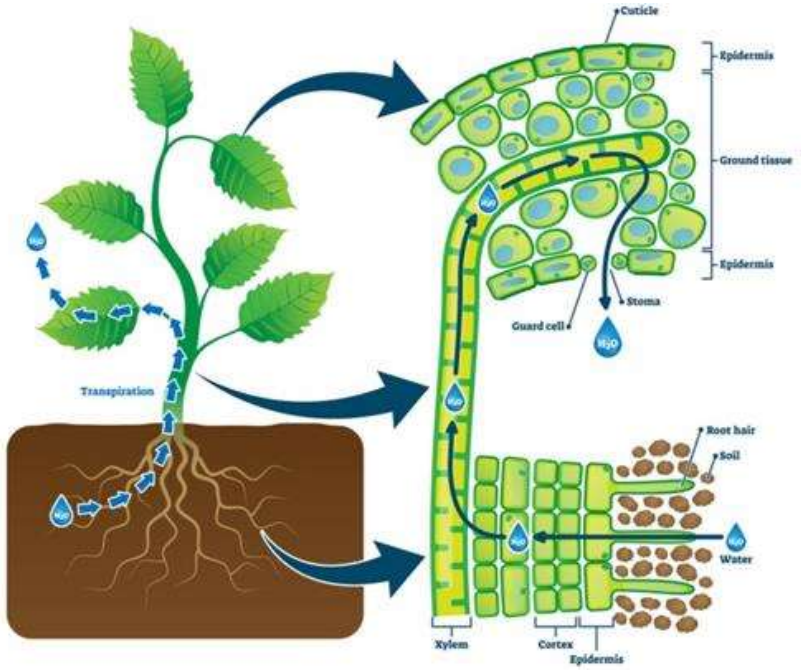
- When the proboscis of the sucking aphid is cut, it is found to have penetrated into the phloem tube and when its contents of the proboscis are analyzed.
- It is found to contain products of photosynthesis (sucrose) which are transported to the bark through the phloem

Radio Active Tracers

- If a plant is exposed to CO2 labeled with radioactiv C-14, the C-14 becomes incorporated into the end products of photosynthesis which are subsequently detected in the stem.
- That these substances are confined to the phloem and can be shown by cutting sections of the stem, placing the sections in contact with photographic film and making auto radiographing it is found that the sites of radioactivity correspond precisely to the positions of the phloem.

TRANSPIRATION

•This is a process by which plants lose water in form of water vapour mainly through leaves to the atmosphere. Transpirati



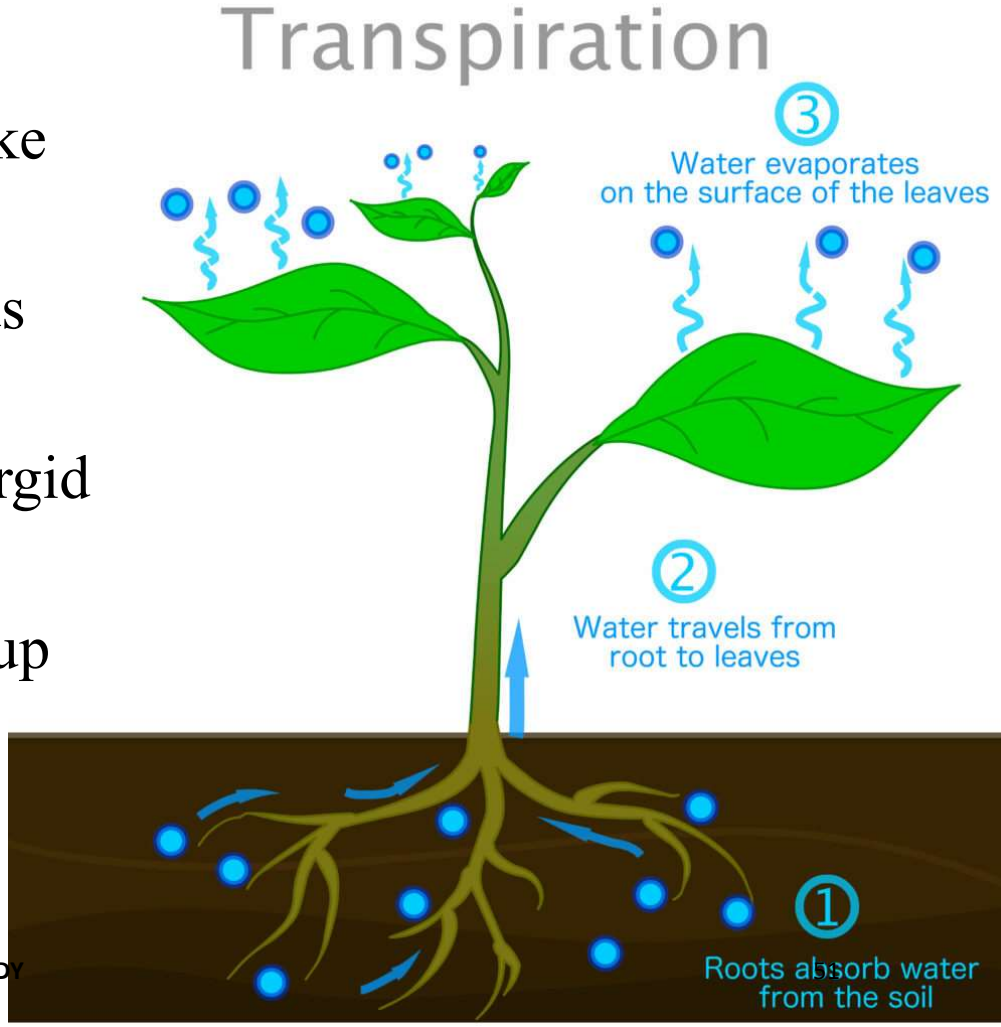
•**TYPES OF TRANS**

- **Stomatal transpiration:** This is the transpir This contributes up to 80-90% of water lost.
- **Cuticular transpiration:** This occurs throug about 20% of the water lost.
- **Lenticular transpiration:** This occurs thro and accounts for about 0.1% of the water lost

Water can also be lost from the plants as water droplets in a process called guttation through special structures called hydrates found on leaf types or margins

IMPORTANCE OF TRANSPIRATION

- Results in the absorption of water and its movement up the plant to aid processes like photosynthesis.
- Contribution to maintenance of continuous stream of water throughout the plant.
- Transported water keeps the plant cells turgid and cools the plant.
- Results in the movement of mineral salts up the plants to where they are needed.



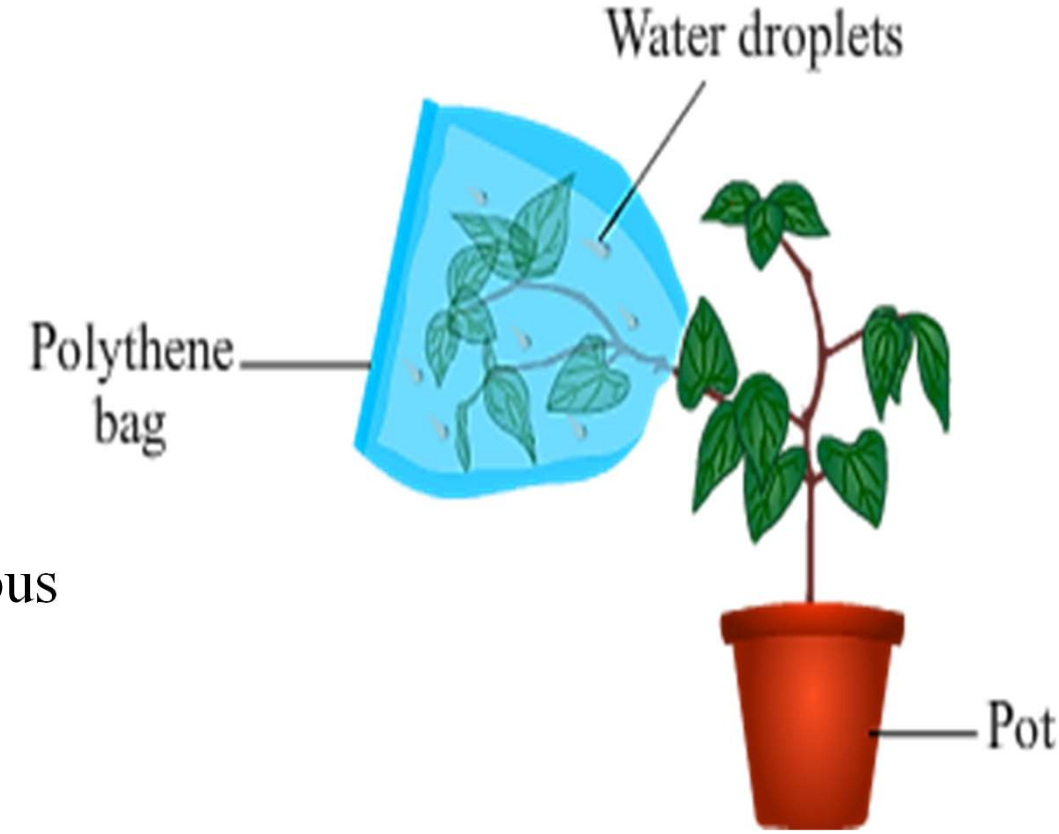
DISADVANTAGES / DANGERS OF TRANSPIRATION

- Excessive water loss from the plant may lead to wilting, drying and even death of the plant.
- Water may lead to over cooling which affect metabolic activities
- Over absorption of mineral salts with water lead to soil exhaustion.

AN EXPERIMENT TO SHOW THAT WATER IS LOST MAINLY FROM LEAVES DURING TRANSPIRATION

Materials

- Potted plant
- Polythene paper
- String
- Cobalt (II) chloride paper or anhydrous copper (II) sulphate



PROCEDURE

- Tie polythene around the tin of the potted plant. Using a string to avoid evaporation of water from the soil surface.
- Tie transparent polythene around the leafy shoot of the plant.
- Set up another similar control experiment but with leaves removed and dry plant.
- Leave the experiment to settle for 3 hours in bright sunlight.
- Remove the polythene around the leafy shoot and test the drops of liquid inside the polythene using anhydrous copper (ii) sulphate / cobalt (ii) chloride paper.

Observation

- A vapour forms inside the polythene and turns into drops / liquid which turn anhydrous copper (ii) sulphate from white to blue or blue cobalt (ii) chloride paper to pink.
- No vapour is observed from experiment with no leaves / dry plant.

Conclusion

- Transpiration occurs from the leaves

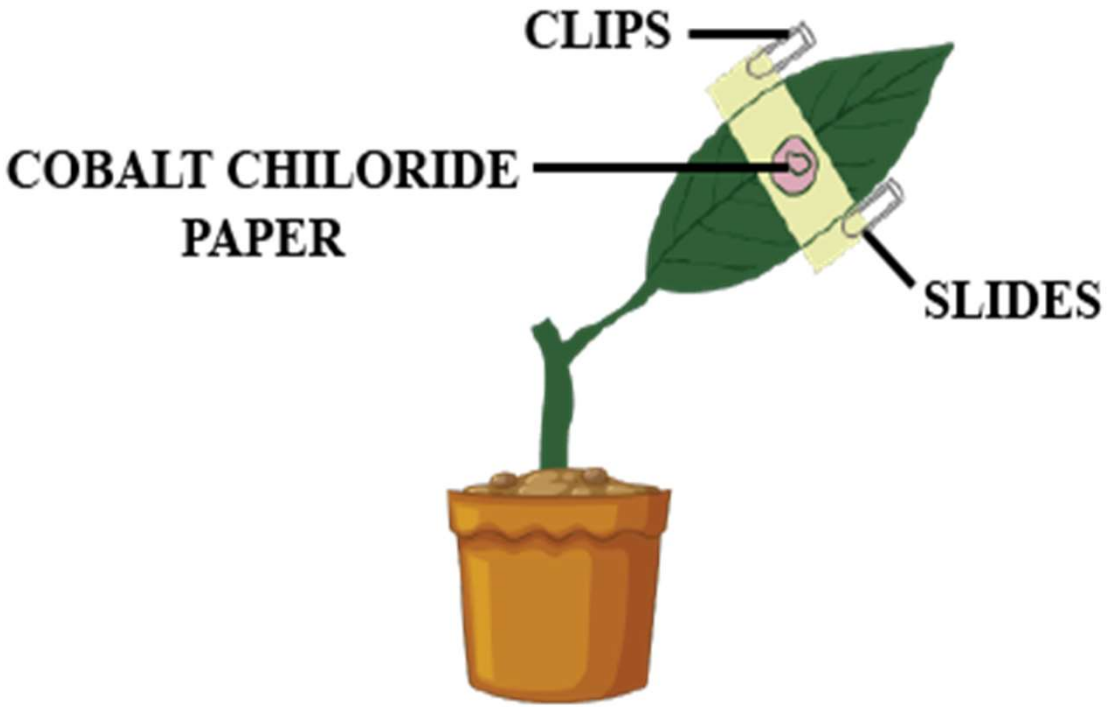
Note

- A control experiment may also be a covered pot where the plant shoot has been cut off.

EXPERIMENT TO COMPARE TRANSPIRATION RATES ON BOTH SURFACES OF A LEAF

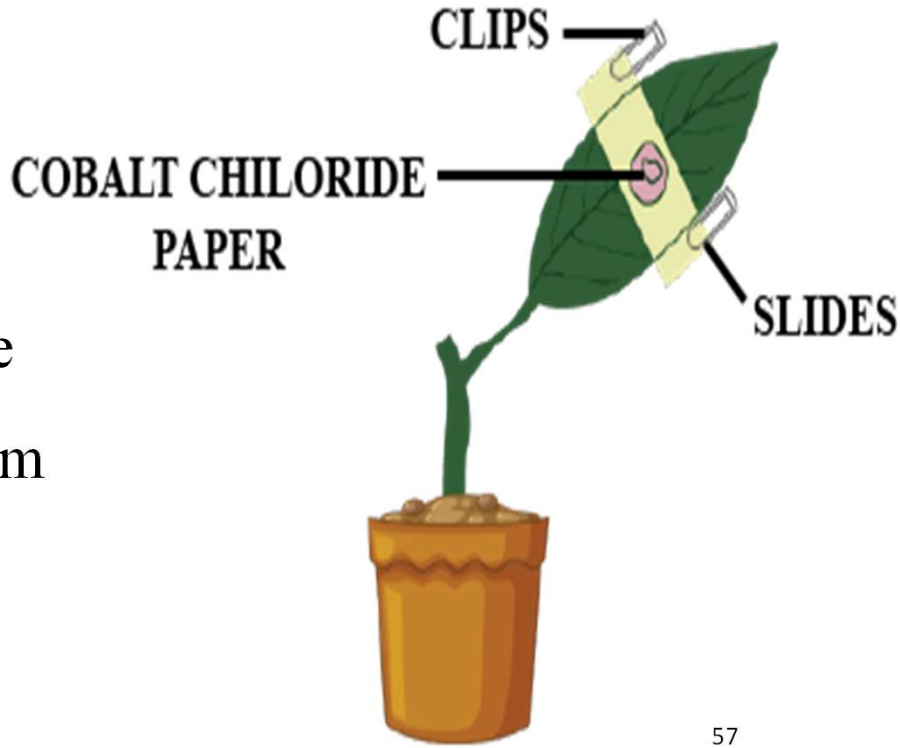
Apparatus

- ❑Potted plant
- ❑Glass slide
- ❑Cobalt (ii) chloride paper
- ❑Rubber bands



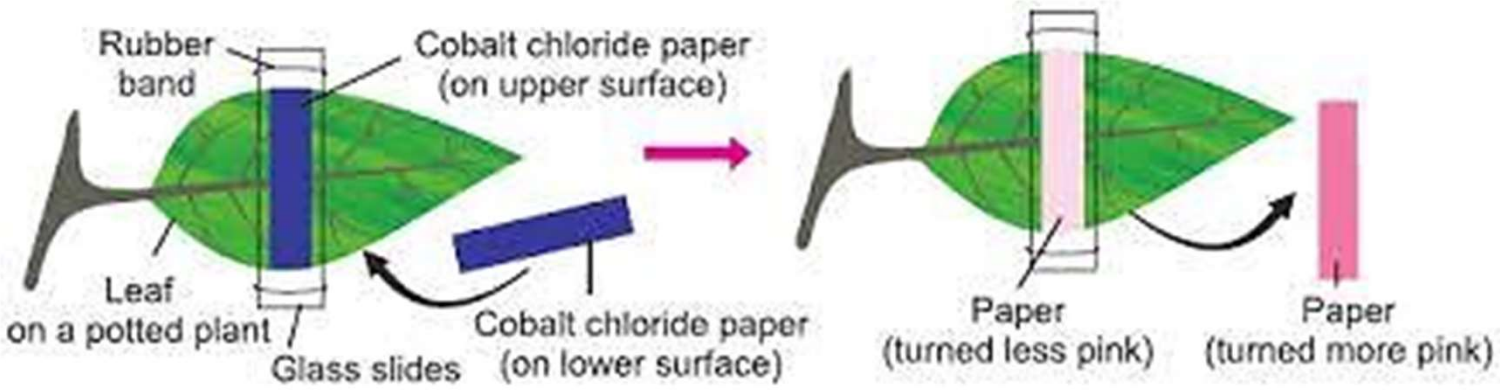
PROCEDURE

- Fix pieces of Cobalt (ii) chloride paper on the upper and lower surfaces of a leaf still to the plant with glass slides.
- Tie the slides using the rubber bands
- Note the time taken for the Cobalt (ii) chloride paper on each slide to turn / change colour from blue to pink.



RESULTS.

- Observation
- The lower surface cobalt (ii) chloride paper turns pink faster than that on the upper surface.
- Conclusion
- The lower surface has a higher transpiration rate than the upper surface. This is due to numerous stomata on the lower surface of the leaf



FACTORS THAT AFFECT THE RATE OF TRANSPIRATION

- **Temperature**: Increase in temperature increases the rate of transpiration. This is because high temperatures provide latent heat of vaporization which increases the evaporation of the water leading to more water to be lost.
- Temperatures also increases the kinetic energy of the air molecules around the leaf which causes them to move further apart and this increases rate of diffusion from the leaf
- **Relative humidity**: As humidity increases, the rate of transpiration decreases. This is because the environment becomes saturated with the water vapour. This reduces the diffusion gradient hence water vapour is adsorbed on the leaf surface
- **Wind**: Rate of transpiration is higher in windy air than in still air. This is because wind helps / assists to remove water vapour in the air around the leaf and creates more spaces that can take up more water vapour

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- **Light intensity**: Rate of transpiration is high in the presence of light and low in the dark. This is because high light intensity result in high rate of photosynthesis which increase the sugar concentration in the guard cells which lead to wide opening of the stomata leading to more evaporation from the plant (also light provide heat which increase evaporation from the leaf stomata.
- **Atmospheric pressure**: Humidity decreases with decrease in atmospheric pressure. Hence decrease in atmospheric pressure greatly increases the rate of transpiration due to decreased humidity.

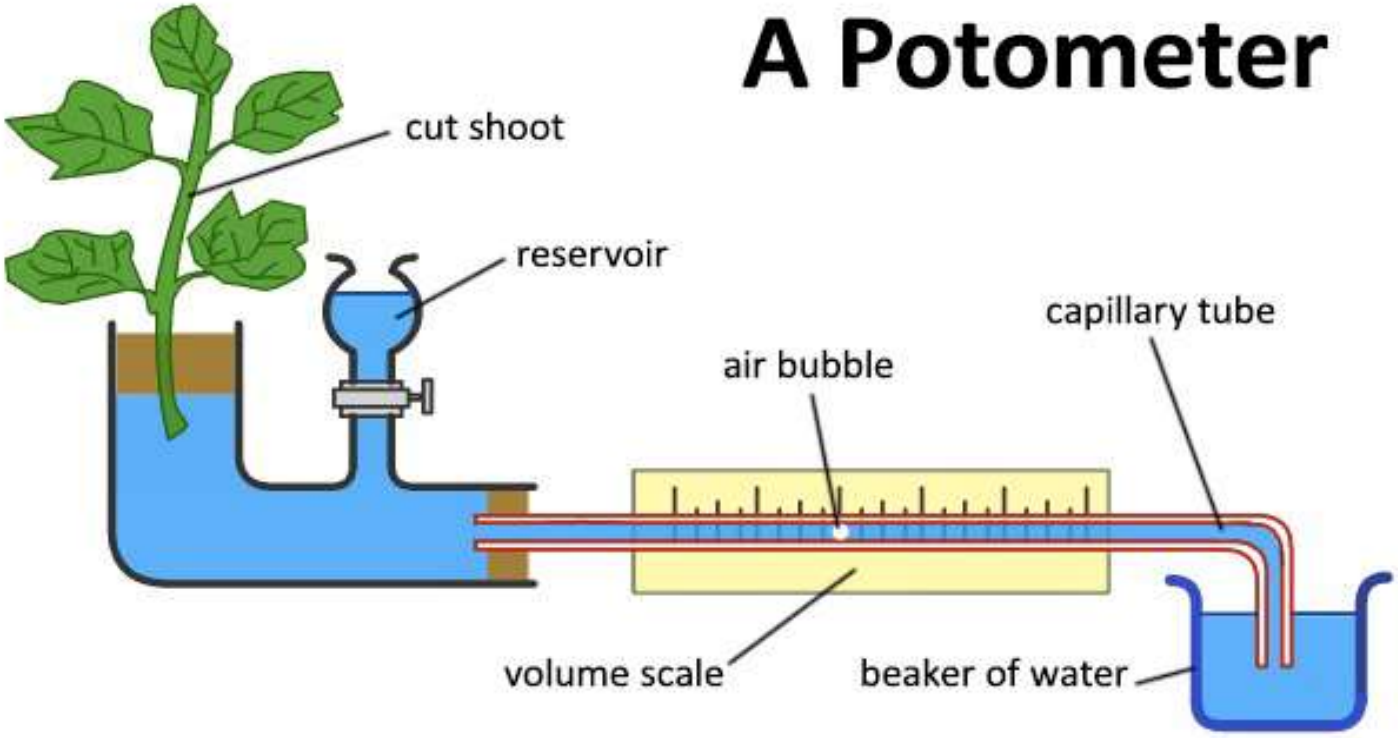
NON ENVIRONMENTAL FACTORS

- **Distribution of stomata**: The rate of transpiration is low when more stomata are on the lower side and is higher when more stomata are on the upper side of the leaf.
- **Number of stomata**: The greater the number of stomata, the higher the rate of transpiration because more water vapour is lost through the stomata.
- **Surface area for transpiration**: Plants with wide/broad leaves have a larger surface for transpiration thus they experience a higher rate of transpiration.
- **Thickness of the plant cuticle**: The rate of transpiration decreases with increase in thickness of the cuticle. For that reason, plants found in deserts have extremely thick cuticle than those in tropical regions.

AN EXPERIMENT TO MEASURE THE RATE OF TRANSPIRATION

Materials.

- Freshy leaf shoot
- Water
- Potometer
- Ruler



PROCEDURE

- A leafy shoot of a plant is cut under water to prevent air bubbles from entering as these would block the xylem vessels.
- The potometer is filled with water.
- The leafy shoot is fixed into the cork and then fitted into the mouth of the potometer vessel.
- Vaseline is smeared at the interface of the shoot and the cock to prevent entry of air into the apparatus.
- A single air bubble is introduced at the open end of the capillary tube by touching the open end briefly under water and then release.
- At a given mark V1, reached by the air bubble, a clock is started and after a given time t, the new position of the air bubble V2, is noted and recorded

$$\text{Rate of transpiration} = \frac{\textit{distance moved by the air bubble}}{\textit{time taken}}$$

$$= \frac{V2 - V1}{t}$$

- In any given set of environmental conditions, about 3 experiments can be performed, resetting the air bubble after each experiment by opening the tap and then close.
- Average rate is then calculated and taken as the rate of transpiration in that environment.
- The set up can be moved to different environmental conditions and rate of transpiration determined in the same way.

NOTE

- The potometer works on assumption that water lost from the leaves during transpiration equals water absorbed by the plant.
- Therefore the potometer:
- Directly measures the rate of water uptake/ absorption of the shoot and
- Indirectly measures rate of water loss / evaporation of water/ transpiration from the leaves

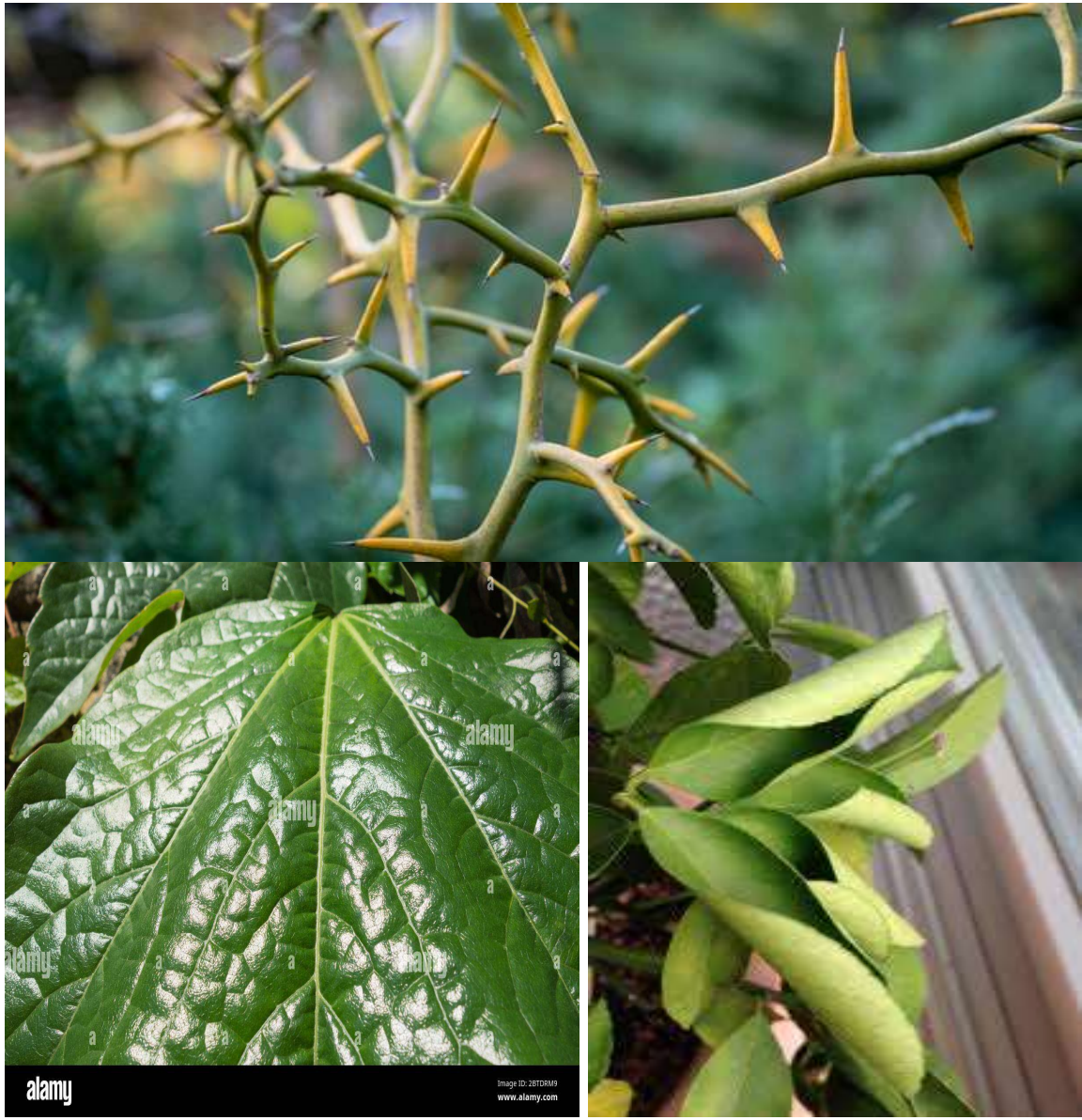
PRECAUTIONS TAKEN WHEN USING A POTOMETER IN ORDER TO ENSURE ACCURATE RESULTS

- A leafy shoot should be used to ensure significant water loss.
- The shoot must be cut under water to prevent air from entering and blocking the xylem vessels.
- The whole apparatus must be full of water.
- A single air bubble must be present in the capillary tube fir each experiment.
- Air bubble must be reset to zero mark before each experiment
- A graduated capillary tube must be used in order to clearly read results.
- Air bubble should not cross the T- function at the reservoir.

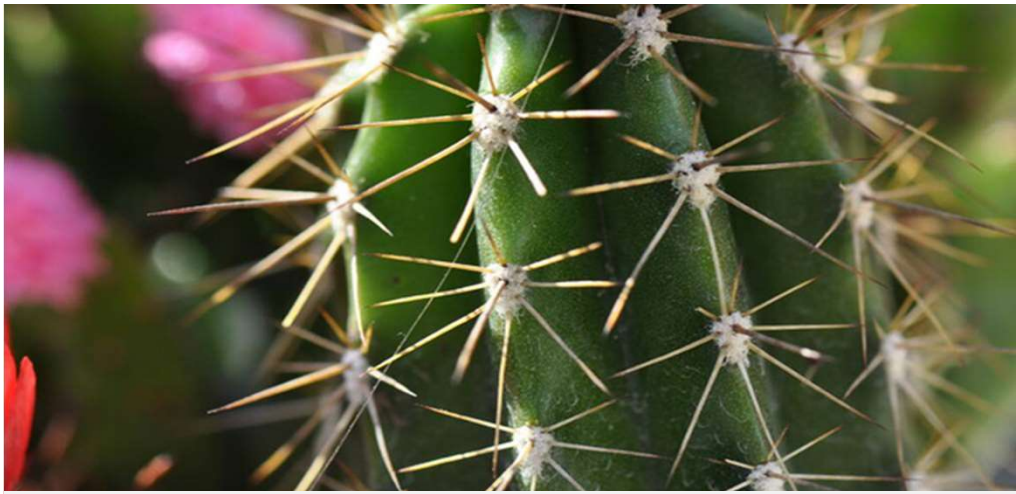
ADAPTATIONS OF PLANTS TO REDUCE TRANSPIRATION RATE

- Shedding off of leaves in deciduous plants to reduce transpirations since most of it occur from the leaves
- Reducing the number, size and distribution of the stomata and only on lower epidermis
- Structural adjustments in stomata i.e. some plants have sunken stomata and others have hairy stomata which reduces evaporation from them.

- Reduction in leaf structure i.e. some plant leaf are reduced to narrow or thorny / spines structures that reduce surface area over which transpiration occurs.
- Rolling of leaves to create a humid atmosphere around the stomata in order to reduce water loss.
- Possession to thick cuticle of the leaves to prevent water loss through it.



- Thick leaves that store water
- Changes in the rhythm of stomata opening i.e. they close during day and open at night when temperatures are very low.
- They shed off their leaves in extremely hot environment to cut down water loss.
- Reversed opening and closing of stomata. Stomata open at night and close during the day when its rate of transpiration is likely to be higher



ALWAYS AIM FOR EXCELLENCE

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