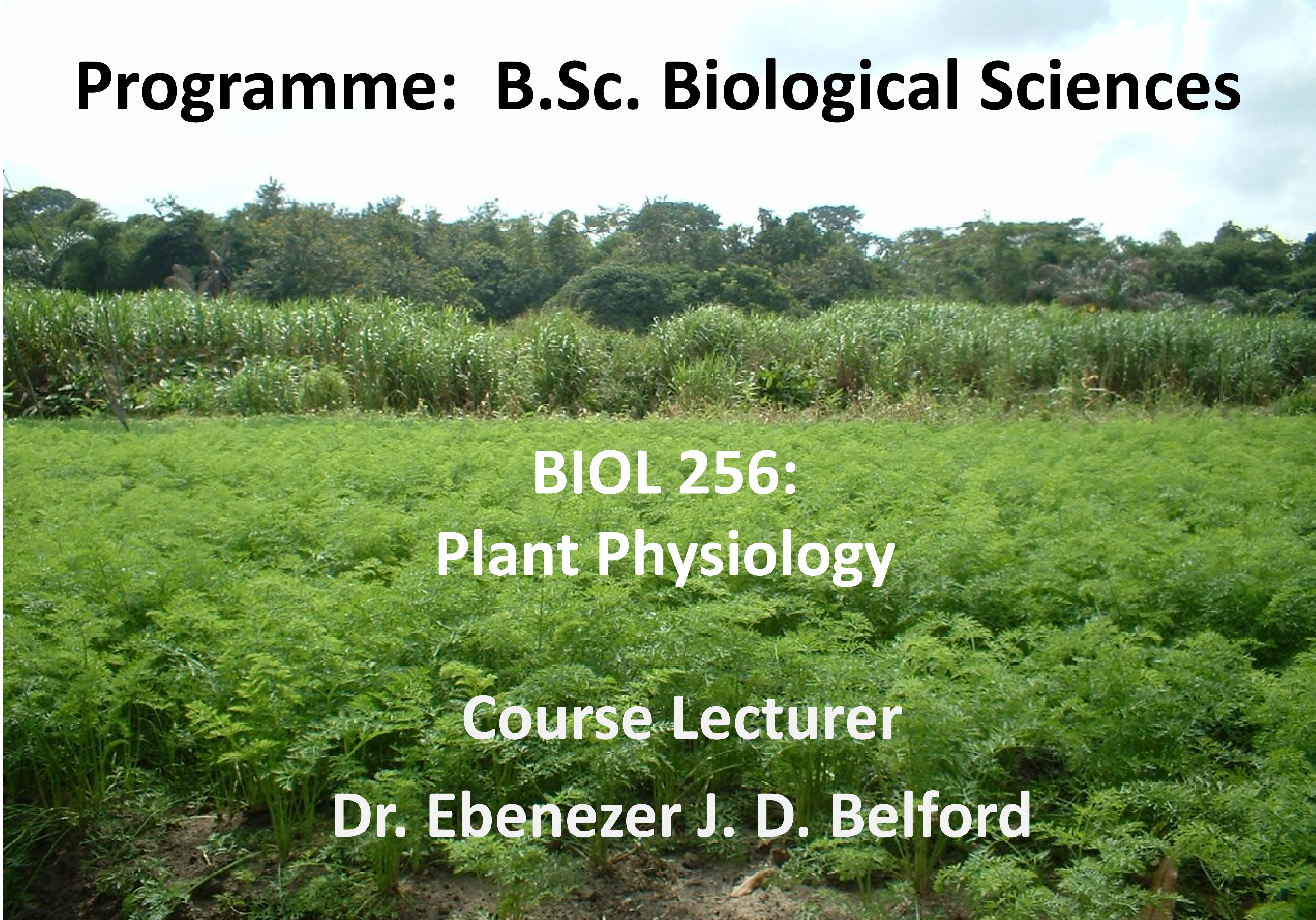


Programme: B.Sc. Biological Sciences

BIOL 256:
Plant Physiology

Course Lecturer

Dr. Ebenezer J. D. Belford

BIOL 256 – PLANT PHYSIOLOGY

Year Two - Semester Two

- **Three (3) Credit hours**
- **Two (2) hours - Theory**
- **Three (3) hours - Practical**

Assessment Requirements

- ✓ Quiz
- ✓ Mid Semester Examination
- ✓ Practical Assignments – Weekly
- ✓ Theoretical Assignments
- ✓ Attendance
- ✓ End Semester Examination 70%

Continuous Assessment 30%

BIOL 256: LECTURE TOPICS

1. PLANT PHYSIOLOGICAL SYSTEMS

- **Colloidal System**
- **Diffusion**
- **Imbibition**
- **Osmosis (*Turgidity*)**
- **Plasmolysis**

2. CONCEPT OF WATER POTENTIAL

- **Free Energy and Chemical Potential**
- **Water Potential (Energy and Pressure units)**
- **Components of Water Potential: *Osmotic and Pressure Potential***
- **Measurements of Water Potential**

LECTURE TOPICS *contd.*

3. WATER RELATIONS OF WHOLE PLANTS

- **Composition of Water in Plants**
- **The Ascent of Sap:**
  - **Absorption – Uptake of water from the soil (source)**
  - **Conduction – Movement of water through plants (channel)**
  - **Transpiration – Evaporation of water from leaves**
- **Physiology of Stomata (mechanism of stomata action)**

4. ABSORPTION OF MINERAL SALTS

- **Uptake by Roots (movement of ions from soil to roots)**
- **Donnan Equilibrium**
- **Accumulation**
- **Translocation in the Xylem**
- **Factors affecting Salts Absorption**

LECTURE TOPICS *contd.*

5. **TRANSLOCATION OF SOLUTES**

6. **THE ROLE OF AUXIN AND WATER IN CELL ENLARGEMENT**

7. **STRESS PHYSIOLOGY**

- **Plant Moisture Stress**
- **Plant Process Sensitive to Water Stress**
- **Plant Productivity and Water Stress**

8. **PHYSIOLOGY OF FLOWERING**

- **The Stage of 'Ripeness of flower ' and 'Earliness'**
- **Stages in Floral Transformation**
- **Photoperiodism and Flowering**
- **Vernalization**

WHOLE PLANT PHYSIOLOGY

- **Plant Growth and Development (Seeds, fruits, hormone)**
- **Plant Water Relations (Transport of water, stress physiology)**
- **Plant Metabolism (Photosynthesis and mineral nutrition)**

Recommended texts for further reading

1. Stern, K. (2003). Introductory Plant Biology
2. Taiz, Lincoln and Zeiger, Eduardo (2002) Plant Physiology. 3rd Edition.
3. Street, H. E and Opik H (1984). The Physiology of Flowering Plants: Their growth and development. Edward Arnold, London.
4. Sutcliffe, J. F (1979). Plants and Water.
5. Sutcliffe, J. F and Baker, D. A (1974). Plants and Mineral salts.
6. Richardson Michael (1975). Translocation in Plants. Studies in Biol.
7. Kramer, P. J (1983). Water Relations of Plants. Academic Press, London.
8. **Any advance Biology Text**.

REQUIREMENTS FOR PRACTICAL CLASSES

- ✓ A Laboratory (practical) file is essential. Any hard cover file with A4 paper to fit will be appropriate. In it you should record all protocols, diagrams, observations and results on practical assignments.

- ✓ Diagrams must be drawn with a pencil. Use pencils with soft lead, preferably HB. Label and rule lines in pencil, as this will facilitate correction.

- ✓ Protective garment. Lab coat, designed to protect from direct exposure to dangerous chemicals and infectious materials.

Course overview

Plant Physiology is a sub-discipline of Botany concern with the functions of plants, their cells and tissues.

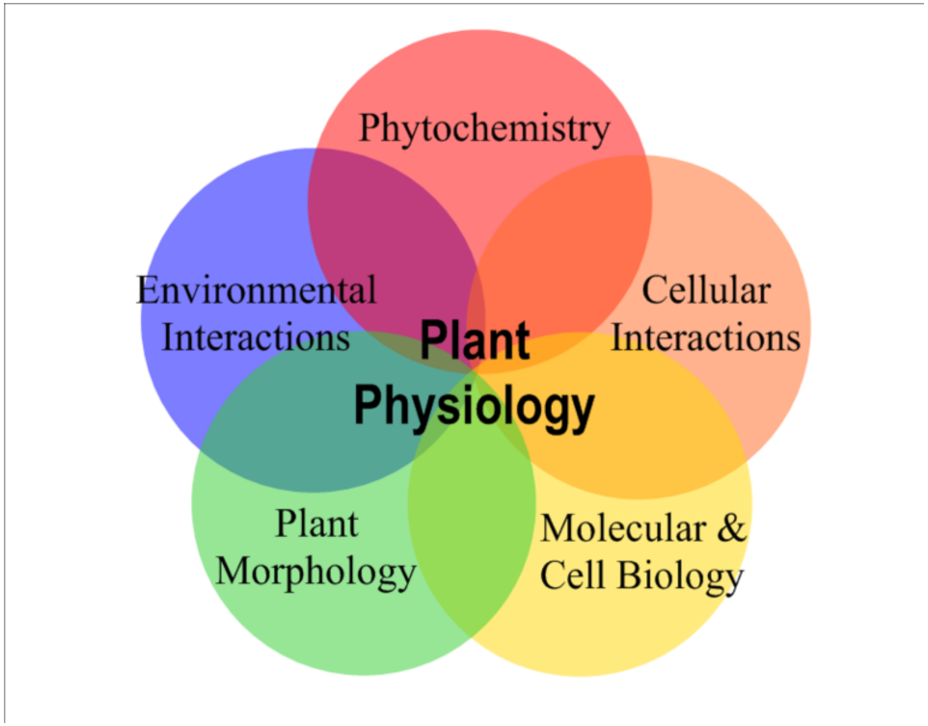
It includes the study:-

- ✓ **Of all the internal activities of plants; those chemical and physical processes associated with life as they occur in plants.**
- ✓ **Of biological and chemical processes of individual plant cells.**
- ✓ **Of the interactions between cells and tissues. The processes by which transport occur.**
- ✓ **Of how plants control or regulate internal functions.**
- ✓ **Of how plants respond to conditions and variation in the environment.**

Course overview *contd.*

Closely related fields of study include:-

- **Plant Morphology and Anatomy**
- **Plant Ecology**
- **Phytochemistry**
- **Cell Biology and**
- **Molecular Biology**



- The course will review pre-tertiary studies in Plant Science.

Objectives of the course

At the end of the course, you should be able to:

- **Define** and **explain** with examples the various concepts in Plant Physiology.
- **Distinguish** between types of Plant Physiological systems.
- **Identify** and **distinguish** between Plant biological and physical processes of individual plant cells.
- Get detailed **understanding** of the origin and mechanism of transport in plant.
- Get an **insight** to the physiological functions of plants, in responds to conditions and variation in the environment.

BACKGROUND INTRODUCTION TO PLANT RELATED DISCIPLINES

- **BIOLOGY:-**

  Science that deals with the study of living things.

- **SCIENCE:-**

  The systematic study of the structure and behaviour of the physical and natural world through observation and experiment.

LIVING THINGS

Consists of two major groups;

PLANTS and ANIMALS

**BOTANY:-**

Deals with the study of PLANTS.

**ZOOLOGY:-**

Deals with the study of ANIMALS.

BRANCHES IN PLANT BIOLOGY (BOTANY)

- **Cytology:-** Study that deals with the cell and its structure, with special reference to the behaviour of the nucleus.
- **Histology:-** Study of the detailed structure of tissues making up a particular organ.
- **Anatomy:-** The study of the gross internal structure of plant organs.
- **Morphology:-** Study of the external forms and features of plant organs.

BRANCHES IN PLANT BIOLOGY (BOTANY) Contd.

- **Taxonomy/Biosystematics:-** The identification, description and classification of plants into various groups.

- **Ecology:-** The study of the interrelationship between plants and their environment.

- **Ethnobotany:-** Study of the use of plants by indigenous peoples.

- **Paleobotany:-** Study of the ancient forms of plants preserved in the form of fossils.

BRANCHES IN PLANT BIOLOGY (BOTANY) Contd.

- **Genetics:-** Study of the inheritance of parental characteristics by offspring.

- **Plant Geography:-** Deals with the distribution and factors responsible for the distribution of plants on the earth.

- **Plant Physiology:-** Is the study of the mechanical, physical and biochemical functions of plants. Form and structure of plants are correlated to its functions.

APPLIED PLANT SCIENCE

- **Economic Botany:-** Utilization of plants and products for the well being of mankind.
- **Agronomy:-** Cultivation of crops for food industry.
- **Horticulture:-** Deals with the cultivation of plants for flowers and fruits.
- **Plant Pathology:-** Diagnosis, cure and prevention of plant diseases.
- **Pharmacognosy:-** Study of medicinal plants.

APPLIED PLANT SCIENCE Contd.

- **Forestry:-** Utilization of forest plants.
- **Plant Breeding:-** Cross breeding of plants to evolve improved types.
- **Biotechnology:-** Exploitation of biological processes for industrial and other purposes.
- **Food Science and Technology:-** Process and utilization of food.
- **Natural Resource Management:-** Conservation and sustainable use of renewable plant materials and products.

1. PLANT PHYSIOLOGICAL SYSTEMS

1.1 Colloidal System

1.2 Diffusion

1.3 Imbibition

1.4 Osmosis (*Turgidity*)

1.5 Plasmolysis

1.0 Plant Physiological Systems

1.1 Colloidal System

- A **Colloid** is a **homogenous** non crystalline mixture consisting of (large molecules or ultramicroscopic) **particles** of one substance dispersed evenly in another substance (the **medium**) which is mostly a liquid or semi solid.
- In many colloids the particles are stable whilst in others they are unstable reacting under slight chemical or physical changes.
- Mostly they are not filterable through a parchment membrane.

1.0 Plant Physiological Systems *contd.*

1.1 Colloidal System *contd.*

Colloidal particles can be divided into two groups:-

1. Those which diffuse readily e.g. salt, sugar, urea are termed ***crystalloids*** (they generally exist in crystalline forms).

2. Those which diffuse slowly are termed ***colloids*** e.g. albumen, gum, starch.

1.0 Plant Physiological Systems *contd.*

1.1 Colloidal System *contd.*

The **colloidal mixture**

- maybe ***fluid*** and is referred to as a ***sol***
- or it may be ***viscous*** and is referred to as a ***gel***
- or it maybe an ***emulsion***, that is a fine dispersion of minute droplets of one liquid in another liquid in which it is not soluble or miscible e.g. milk.

1.0 Plant Physiological Systems *contd.*

1.1 Colloidal System *contd.*

A **colloidal solution (system)** is essentially two phase system:-

I. The ***disperse phase*** or ***discontinuous phase*** consisting of discrete particles.

II. And a ***dispersion medium*** or **continuous phase** consisting of the medium (solid, liquid or gaseous).

When the dispersion medium is water the colloidal solution is referred to as a ***hydrosol***.

1.0 Plant Physiological Systems *contd*.

1.1 Colloidal System *contd*.

Colloidal solutions in which a **liquid** is the dispersion medium can be classed into two groups:-

- ***Lyophobic*** – liquid hating
- ***Lyophilic*** – liquid loving

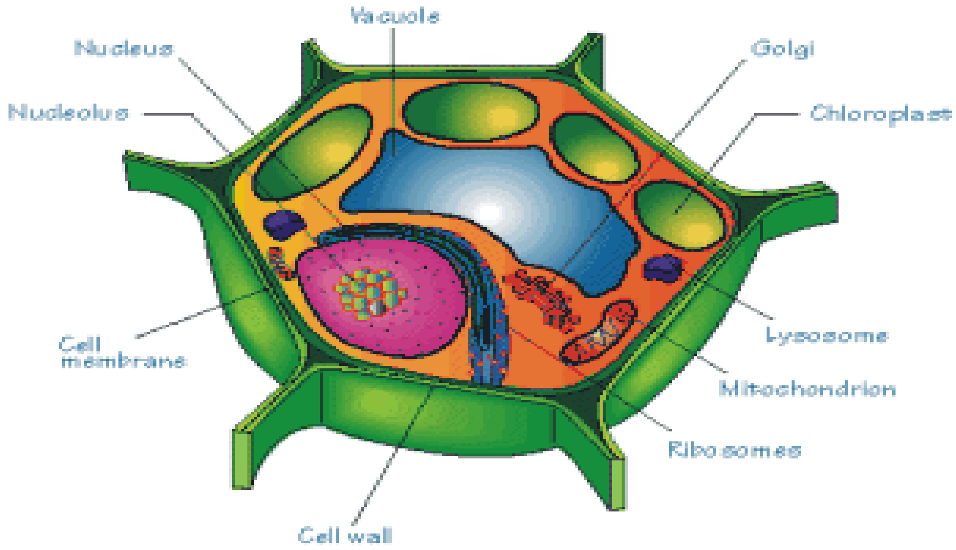
Specifically when **water** is the dispersion medium the groups are referred to as:-

- ***Hydrophobic*** – water hating
- ***Hydrophilic*** – water loving

1.0 Plant Physiological Systems *contd.*

1.1 Colloidal System *contd.*

In the case of the protoplasm (which is the living physiological unit of the cell) the dispersion medium is water, with dissolved salts and other substances and colloidal particles of proteins dispersed through it.



1.0 Plant Physiological Systems *contd.*

1.1 Colloidal System *contd.*

Colloids can be classified as follows:-

Medium / Phases		Dispersed phase		
		Gas	**Liquid**	**Solid**
Continuous medium	**Gas**	**NONE** (All gases are mutually miscible)	**Liquid aerosol** Examples: fog, mist, hair sprays	**Solid aerosol** Examples: smoke, cloud, air particulates
	Liquid	**Foam** Example: whipped cream	**Emulsion** Examples: milk, mayonnaise, hand cream	**Sol** Examples: pigmented ink, blood
	Solid	**Solid foam** Examples: aerogel, styrofoam, pumice	**Gel** Examples: agar, gelatin, jelly, silicagel, opal	**Solid sol** Example: cranberry glass

1.0 Plant Physiological Systems *contd.*

1.2 Diffusion

This is the movement of **molecules** or **ions** of a solute/solvent, liquid or gas from the region of **high** concentration to that of a **lower** concentration.

The molecules or ions in the system are in continuous **motion** following straight paths at different speeds, according to their specific nature and surrounding conditions.

1.0 Plant Physiological Systems *contd.*

1.2 Diffusion

- Molecules that move from a region of high concentration to a region of lower concentration are said to be moving ***along a diffusion gradient***.
- Molecules that move in the opposite direction are said to be moving ***against a diffusion gradient***.

The process continues until equilibrium is reached (that is the molecules are uniformly distributed throughout the system).

1.0 Plant Physiological Systems *contd.*

1.2 Diffusion

- **Diffusion is involved in many plant processes, such as gas exchange and the movement of nutrients towards root surfaces.**

- **For instance, diffusion is the mechanism for most, if not all, steps by which CO_2 from the air reaches the sites of photosynthesis in chloroplasts.**

- **Molecules are able to move from one cell to the other following the law of diffusion.**

1.0 Plant Physiological Systems *contd.*

1.2 Diffusion – Fick's Law of Diffusion

The rate of diffusion in liquid systems is demonstrated by Fick's Law of diffusion which states that:-

$$\frac{dv}{dt} = -Da\,\frac{dc}{dl}$$

Where **dv** is the amount of substance diffusing across an area **a** in a time **dt**. **D** is the ***diffusion coefficient*** of the substance in this particular system; **dc** is the difference in concentration of the substance at two points **dl** cm apart. The negative sign takes account of the fact that net diffusion is from a region of higher to one of lower chemical potential.

1.0 Plant Physiological Systems *contd.*

1.2 Diffusion – Fick's Law of Diffusion

- The diffusion coefficient is a **proportionality constant** that measures how easy the substance moves through a particular medium.
- Larger molecules have smaller diffusion coefficients.
- Movement also depends on the medium (diffusion in air is much faster than diffusion in liquid).
- A substance diffuse faster when the concentration gradient is steeper or diffusion coefficient is increased.

1.0 Plant Physiological Systems *contd.*

1.2 Diffusion

Diffusion key facts:

- ✓Diffusion brings about the net movement of matter and minimizes concentration gradient.
- ✓Is not a chemical reaction.
- ✓Is a spontaneous process.
- ✓Is a passive form of transport.
- ✓Occur only if there is a gradient

1.0 Plant Physiological Systems *contd.*

1.3 Imbibition

It is the process whereby materials in arid conditions absorb water (it is a special case of water movement).

- ✓ The process occurs where there is an affinity between the materials and water.
- ✓ The material take up water by surface attraction and increase in volume often several times their original volume (whether they are living or dead) e.g. starch, cellulose.
- ✓ Imbibition is the initial step in germination of seeds, with the imbibition pressure causing the seed coat to swell and burst.

1.0 Plant Physiological Systems *contd.*

1.3 Imbibition

- ✓ The force of imbibition is also believed to be involved in the ascent of sap and plays an important part in the intake of soil water by root.
- ✓ In an imbibing system water always moves with some force from a saturated region to a drier region.
- ✓ Colloidal materials (that contain a permanent suspension of fine particles) and large molecules such as cellulose and starch usually develops electrical charges when they are wet.

1.0 Plant Physiological Systems *contd*.

1.3 Imbibition

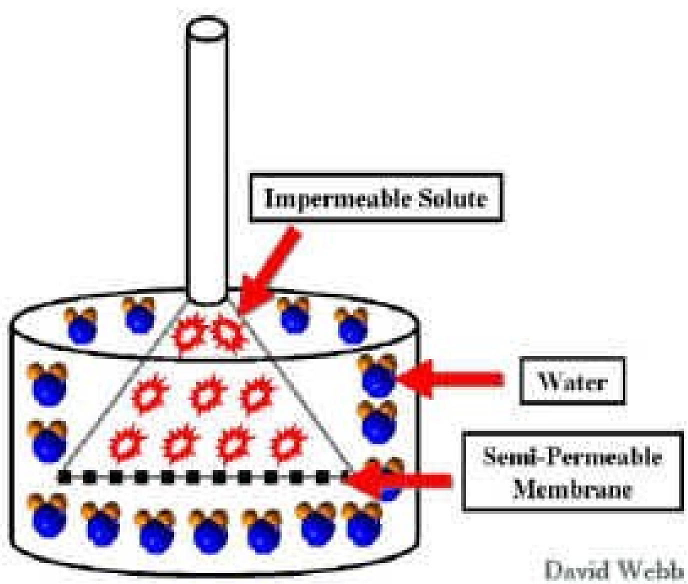
- ✓The charged colloids and molecules attract water molecules which adhere to the internal surfaces of the molecules.

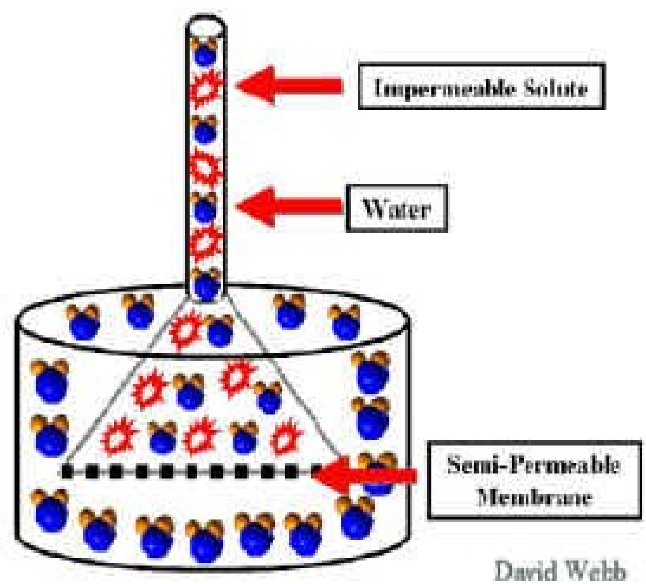
- ✓Since water molecules are polar they become highly adhesive to large organic molecules such as cellulose and cohesive with one another.

1.0 Plant Physiological Systems *contd.*

1.4 Osmosis

It is a process by which water molecules moves (diffuse) across/through a ***semi-permeable*** or ***differentially permeable membrane*** from a region of high water concentration to a region of low water concentration. (It is a special case of water movement).





Osmometer

1.0 Plant Physiological Systems *contd.*

1.4 Osmosis

❖ The semi-permeable membrane **allows** the solvent on one side to pass through freely but at the same time **resist the solute** on the other side so that only a minute quantity can go through.

❖ Membranes which operates this selective type of transmission where different substances diffuse at different rates are said to be ***differentially permeable***, ***semi-permeable*** or ***partially permeable***. The membrane is permeable to water but impermeable to larger molecules.

1.0 Plant Physiological Systems *contd.*

1.4 Osmosis

❖ In plant cells, the **cell membrane** acts as a differentially permeable membrane. By the process of osmosis cells absorbs water into their vacuole until the ***hydrostatic*** or (turgor pressure or pressure potential) stops further flow.

Turgidity:

➢ The outward pressure exerted on the cell wall by the fluid contents of the cell is called ***turgor pressure***. The inward pressure exerted on the cell contents by the stretch cell wall is called the ***wall pressure***.

➢ At this point of full turgor, the turgor pressure is equal and opposite to the pressure of the cell wall (wall pressure). The cell is said to be ***turgid*** and in a condition (state) of **turgidity**.

1.0 Plant Physiological Systems *contd.*

1.4 Osmosis

- Osmosis is the primary means by which water enters plants from their surrounding environment.

- Osmosis is more precisely discuss in terms of potentials. A pressure gradient develops across the semi-permeable membrane when separating a solvent from a solute/solution.

- The pressure which a solution develops in order to permit the uptake of water by osmosis is referred to as ***osmotic potential;*** which is directly related to the concentration of solute molecules in the solution and is now known as ***solute potential***.

1.0 Plant Physiological Systems *contd.*

1.4 Osmosis

Osmosis key facts:-

- ✓The movement of water
- ✓Down a water potential gradient
- ✓Across a partially permeable membrane
- ✓To a solution with a more negative water potential

1.0 Plant Physiological Systems *contd***.**

1.5 Plasmolysis

- This is the shrinking of the cell protoplasm away from its cellulose wall, when placed in an ***hypertonic solution***, resulting as a loss of water through osmosis out of the cell central vacuole.

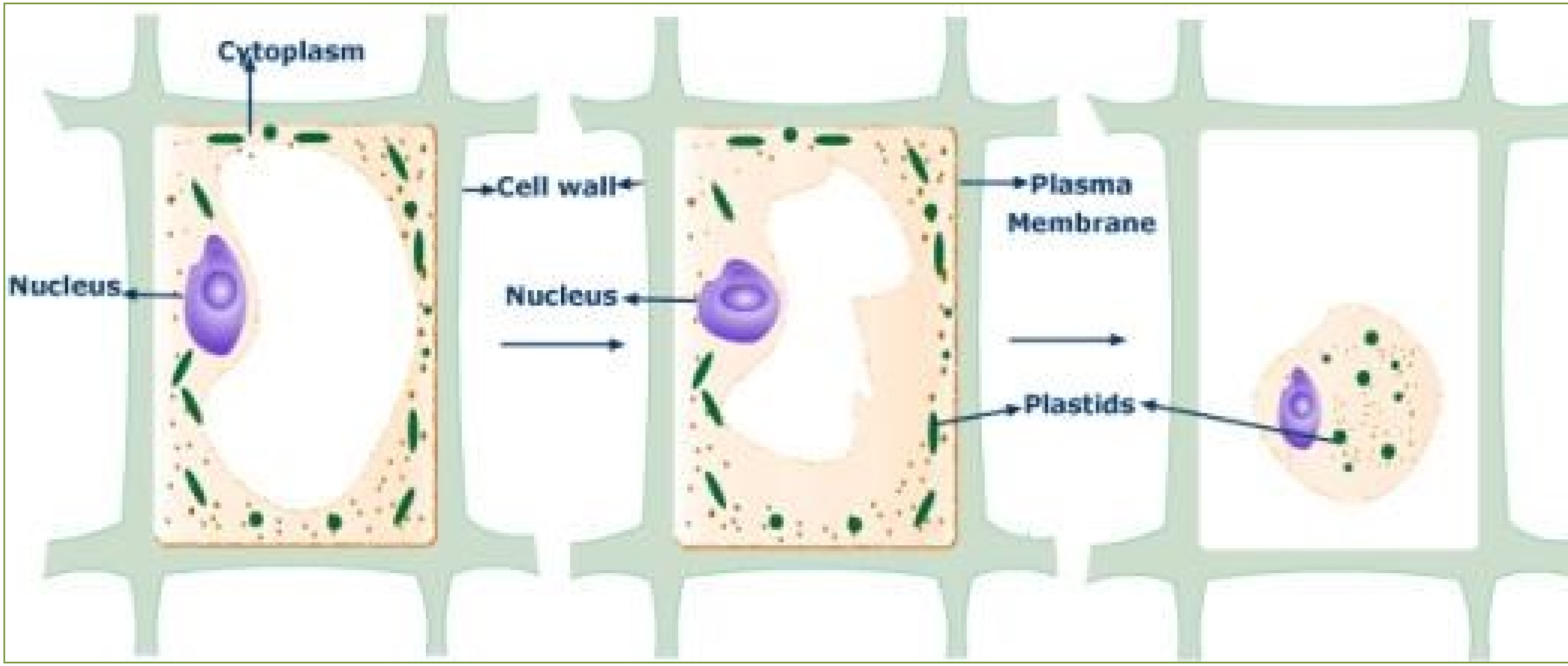
- The water potential inside the cell is ***greater than*** the solution outside causing the net movement of water out into the high concentrated solution.

- The vacuoles which are largely water would disappear and the cytoplasm clumped in the middle of the cell having shrunk away from the wall. Such cells are said to be ***plasmolysed*** or ***flaccid***.
- When this condition is reflected in the whole plant the condition is referred to as ***wilting***.

1.0 Plant Physiological Systems *contd.*

1.5 Plasmolysis

Various Stages in Plasmolysis



A. Normal Cell **B. Incipient Plasmolysis** **C. Plasmolysed Cell**

1.0 Plant Physiological Systems *contd.*

1.5 Plasmolysis

- The point at which the protoplast is just about coming away from the cell wall is termed ***incipient plasmolysis***.

- Whilst the ***cell wall is freely permeable*** to the hypertonic solution the protoplasmic membrane is differentially permeable.

- A solution is said to be ***hypertonic*** when its osmotic potential is greater than that of the cell. It is ***isotonic*** when osmotic potential of solution equal that of the cell and ***hypotonic*** when its osmotic potential is lower than that of the cell.

1.0 Plant Physiological Systems *contd.*

1.5 Plasmolysis

Diffusion Pressure Deficit:

- Also known as the ***water diffusion potential***; it is the measure of the water absorbing power of a cell (the tendency of a cell to draw in water from outside).

- It is the pressure applied on water to drive it into absorbing materials. This varies according to the materials and conditions.

- At plasmolysis the cell would be experiencing a ***diffusion pressure deficit*** (DPD) equal to that of the ***osmotic potential*** (OP).

1.0 Plant Physiological Systems *contd.*

1.5 Plasmolysis

- When a cell which has been plasmolysed is introduced into an hypotonic solution water will continue to enter the protoplast expanding it until it comes in contact with the cellulose wall.

- At this point the DPD will be opposed by the inward pressure of the cellulose wall on the expanding protoplast. The DPD will then be equal to the OP – WP. (DPD = OP – WP).

- As the cell continues to expand the force offered by the cellulose wall increase and the DPD decreases.

- Eventually full turgor is reached when the cell can expand no more. The DPD drops to zero and the OP of the cell sap is equal to the WP.

2.0 Concept of Water Potential

2.1 Free Energy and Chemical Potential

2.2 Water Potential:

(*Energy and Pressure units*)

2.3 Components of Water Potential:

(*Osmotic and Pressure Potential*)

2.4 Measurements of Water Potential

2.0 Concept of Water Potential

2.1 Free Energy and Chemical Potential

- All forms of energy exist in two forms;

  1. Potential energy is stored energy (bonds)

  2. Kinetic energy is energy in action (motion)

- Together these energies are referred to as ***Free Energy***.
- Example: Photosynthesis converts kinetic light energy to potential bond energy and respiration releases it again as kinetic heat or mechanical energy.

2.0 Concept of Water Potential *contd.*

2.1 Free Energy and Chemical Potential

❖ Under Gibbs Free Energy; the energy forms are referred to as ***enthalpy*** (internal energy) and ***entropy***, kinetic energy (state of disorder).

❖ The free energy (per unit quantity of a substance specifically per gram molecular weight) is called the ***Chemical Potential***. It is an indication of the maximum work that could be done by a system.

❖ It is also the ability (or energy status) of system to do work. Like solute concentration and temperature it is independent of quantity of substance being considered.

2.0 Concept of Water Potential *contd.*

2.2 Water Potential (Energy and Pressure units)

- ***Water potential*** is the chemical potential of water in a system or part of a system, expressed in units of pressure and compared to the chemical potential (also in pressure units) of pure water at atmosphere pressure and at the same temperature.

- The chemical potential of pure water is arbitrarily set at zero.

2.0 Concept of Water Potential *contd.*

2.2 Water Potential (Energy and Pressure units)

- Water potential is the measure of the free kinetic energy of water **or** the tendency of water to leave a system.
- It is represented by the symbol **Ψ** (psi).
- It can also be represented by $\boldsymbol{\Psi_w}$ or $\boldsymbol{\Psi_o}$.
- It is measured in units of pressure; Bars, Joules per kilogram (J/kg) or Pascal's (P, KPa, MPa).

2.0 Concept of Water Potential *contd.*

2.2 Water Potential (Energy and Pressure units)

- It is a measure relative to a standard of pure water at atmospheric pressure and same temperature of the system being studied.

- The water potential of pure water is arbitrarily set (given) at zero.
- This is the reference point rather like the redox potential system used in chemistry.
- Hence for pure water, water potential (Ψ) = 0
- Thus the highest value of water potential (Ψ) in a system is zero.

2.0 Concept of Water Potential *contd.*

2.2 Water Potential (Energy and Pressure units)

- As water always moves down a gradient of (Ψ), the difference in water potential ΔΨ constitute the driving force for water movement within systems.

- When the difference in water potential (ΔΨ) of two systems is zero the systems are said to be in equilibrium as there is no net movement of water between them.

- A plant cell placed in pure water will experience an inward movement of water by osmosis, along a water potential gradient.

2.0 Concept of Water Potential *contd.*

2.2 Water Potential (Energy and Pressure units)

- ✓The cellulose cell wall is freely permeable to water and solutes whilst the plasma membrane is freely permeable to water but of limited permeability to solutes.

- ✓The entry of water will cause the swelling of the protoplast, the cell contents, causing a (turgor) pressure (TP) to be applied on the cell wall.

- ✓Further expansion is resisted by a force referred to as wall pressure (WP). The effect of wall pressure and turgor pressure on water potential, Ψ is known as ***pressure potential***.

- ✓It represents the tendency for water to be forced out of the cell and is either zero or positive in value.

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

Factors that affects water potential Ψ

- ❖ **Water in plants and soils is subject to several forces caused by the presence of the disperse/solid phase, dissolved salts, external gas pressure and gravitational field.**

- ❖ **These effects are quantitatively expressed in terms of the potential energy of water.**

- ❖ **Potentials are usually measured in Bars, Joules per kilogram (J/kg) or Pascal's (P, KPa, MPa). (1 bar = 0.987 atm = 10^5Pa =100J/kg)**

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

The total potential or water potential Ψ of a system at any point can be partitioned as follows:-

2.3.1 Solute or Osmotic Potential (Ψ_s or Ψ_π)

- **This is due to the presence of dissolved solutes. It is directly related to the concentration of solutes molecules in a solution.**

- **It is always negative in value. The presence of solutes in the cell sap lowers Ψ_s making it more negative and hence lowers water potential (Ψ).**

In a solution the presence of molecules of solutes prevents water molecules leaving. Thus the water potential of a solution is less than zero:- $\Psi_{solution} < 0$.

2.3 Components of Water Potential

2.3.2 Pressure Potential (Ψp)

- **This is the pressure acting outward on the cell walls and internal membranes in plants.**
- **In soils it is related to the hydrostatic pressure (found) under saturated conditions.**
- **It represent the tendency of water to be forced out of a cell and is either *zero or positive in value*.**

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

2.3.3 Matrix Potential (Ψm)

- This is due to the forces of capillarity, molecular imbibitional forces, colloidal and hydrophilic surfaces (water attracting).

- Water molecules tends to stick to surfaces which lowers the free energy of water and therefore lowers the water potential (Ψ).

- Within fully hydrated cells this surface or matrix effect is regarded as negligible, but in soils, cell walls and dry seeds it is of major significance.

2.3 Components of Water Potential

2.3.4 Gravitational Potential (Ψg)

- This is due to the gravitational forces on water in the plant. In most crop situations the gravitational potential is insignificant and if not, is easily measured.

Thus water potential (Ψ) can be represented by:-

$$\Psi = \Psi_s + \Psi_p + \Psi_m + \Psi_g$$

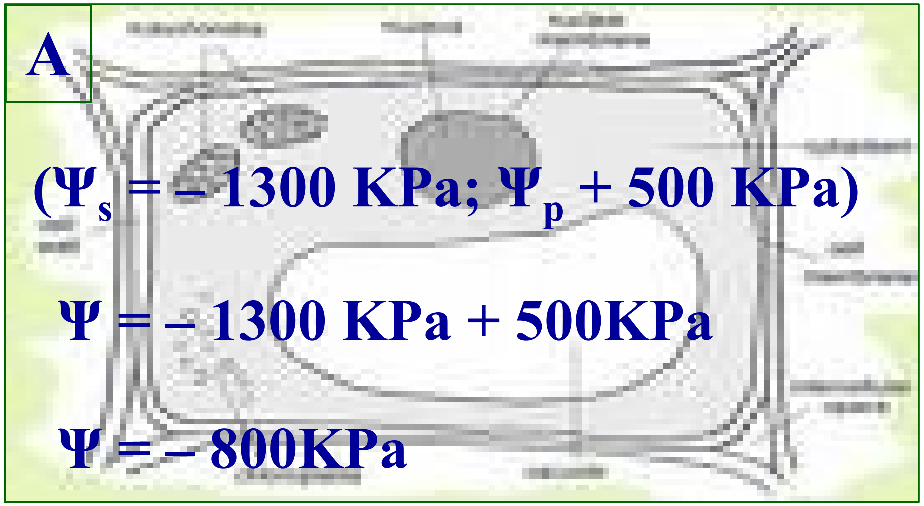
However, since matrix and gravitational potential are *virtually negligible and insignificant* the total water potential in a living plant cell is effectively represented by:-

$$\Psi = \Psi_s + \Psi_p \quad \text{or} \quad \Psi = \Psi_p - \Psi_s$$

2.3 Components of Water Potential – Movement between cells

- Using this formula the movement of water between cells can be determined.

If we have two cells A and B:-

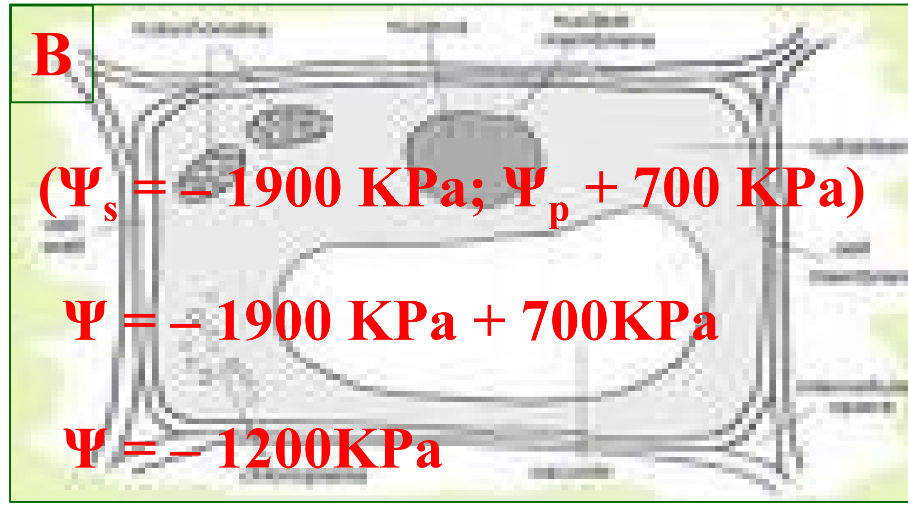


A

$(\Psi_s = -1300\ \text{KPa};\ \Psi_p + 500\ \text{KPa})$

$\Psi = -1300\ \text{KPa} + 500\text{KPa}$

$\Psi = -800\text{KPa}$



B

$(\Psi_s = -1900\ \text{KPa};\ \Psi_p + 700\ \text{KPa})$

$\Psi = -1900\ \text{KPa} + 700\text{KPa}$

$\Psi = -1200\text{KPa}$

- Since –800 is higher (greater) than –1200 water will move by osmosis down a water potential (Ψ) gradient from cell A to B.

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

- **Solute potential and Pressure potential are two main components that effectively represent water potential (which measures the potential for the transfer of water) $\Psi = \Psi_s + \Psi_p$.**
- **The value of pressure at atmospheric pressure equals zero ($\Psi_p = 0$).**
- **Increasing pressure results in positive pressure this is often realized in living cells.**
- **Also quite often pressure is negative as in the dead xylem elements (under tension or suction).**

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

- ✓**Solute potential** is ***always negative*** as adding solute particles always decreases water potential (Ψ).
- ✓**Water potential** (Ψ) can be negative, zero, or positive since pressure potential can be positive and very high.
- ✓**Water potential** (Ψ) of pure water at atmospheric pressure equals zero. $\Psi_{(\text{pure water})} = 0$
- ✓**In a solution** at atmospheric pressure water potential (Ψ) is negative. $\Psi_{(\text{solution})} = -\text{ve}$
- ✓**Pressure potential** (Ψ_p) of pure water under high external pressure above atmospheric pressure is positive.

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

2.3.5 Movement of water in soil-plant-air system

- **In a soil-plant-air system water will move along a gradient from the soil through the plant to the atmosphere.**
- **Water potential (Ψ) is highest in soil and lowest in the atmosphere with intermediate values within various sections of the plant.**
- In the **soil solution** pressure potential (Ψ_p) is equal to zero whilst solute potential (Ψ_s) is slightly negative, since the soil solution is dilute.
- **Therefore, water potential (Ψ) is also slightly negative.**

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

2.3.5 Movement of water in soil-plant-air system

- **In the plant within the xylem tissue water contains few solutes. This makes solute potential (Ψ_s) slightly negative. The water within the cells come under tension causing a negative pressure potential (Ψ_p = –ve).**

- **Hence water potential (Ψ) is more negative in the xylem than in the soil. Thus water will move into plant from the soil.**

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

2.3.5 Movement of water in soil-plant-air system

- **In the leaf cells the solution is more concentrated. This makes solute potential (Ψ_s) more negative.**
- **The movement of water between cells increase pressure making pressure potential positive.**
- **Thus water potential (Ψ) becomes more negative than in the xylem resulting in the movement of water from the xylem into leaf cells.**

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

2.3.5 Movement of water in soil-plant-air system

- In the atmosphere water potential (Ψ) is highly negative than in the leaves causing the movement of water from the leaves into the atmosphere.

- Invariably the atmospheric conditions and the large amount of particles disperse in the atmosphere implies that the solute potential (Ψ_s) is highly negative.

- With pressure at atmospheric level determine at zero, water potential (Ψ) is very negative and equal to solute potential (Ψ_s).

2.0 Concept of Water Potential *contd.*

2.3 Components of Water Potential

Calculation of Solute potential or Osmotic potential

The solute potential (osmotic potential) Ψ_s or Ψ_π can be approximately calculated using the following equation: $\Psi_\pi = -miRT$

Where m is the molar concentration,

- **(i) is the constant that accounts for ionization of solute and other deviations from perfect solutions,**
- **R is the gas constant (0.00831 litre $KJmol^{-1}K^{-1}$), and**
- **T is the absolute temperature, Kelvin (K = ^{o}C + 273)**

If m, i and T are known for a solution then solute potential (osmotic potential) Ψ_s or Ψ_π can be easily calculated for non-ionized molecules such as glucose and sucrose. In dilute solutions i is 1.0 but in other cases i varies with concentration.

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential

- **Water potential or free energy status of water in a system is one of the parameter used to determine the water status of plants or plant water deficit.**

- **Many of the methods used to measure water potential (Ψ) are carried out in the liquid phase and they depend on the principle that if a tissue is in equilibrium with a medium of equal water potential (Ψ) there is no net movement of water into the cells of tissues and therefore the tissue length, weight and volume remains constant.**

- **That is water potential (Ψ) is equal in all parts of the system.**

- **At equilibrium change in water potential (Ψ) is equal to zero, hence ($\Delta\Psi = 0$).**

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.1 Gravimetric (Weight)

- This is a quantitative method base on the difference in weight of plant tissue/organ. It express the change in weight as a percentage (%) of the initial weight of the tissue.

- Plant tissues of uniform size are weighed and distributed equally in a graded series of solutions ranging from dilute (distilled water) to a molar concentration of solute in solution.

- The tissues are allowed to equilibrate in these solutions for one to two hours until all the cells are in equilibrium with the outside medium. The tissues are then reweighed and the difference between the final and initial weight determined.

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.1 Gravimetric (Weight)

- **The change in percentage (%) of initial weight is then plotted against the concentration of graded solutions. The water potential (Ψ) of the cells of the tissue is equal to that of the solution which causes no change in weight.**

Limitations or disadvantages of method

1. **Destructive; plant tissue have to be removed from whole plant.**
2. **Long equilibrium time prevents frequent samplings.**
3. **Limited to availability of plant material.**
4. **Atmospheric conditions may not be the same in laboratory as that observed in the field.**

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.2 Linear Dimension (Length)

- **This is a quantitative method base on the difference in length of plant tissue/organ. It express the change in length as a percentage (%) of the initial length of tissue.**

- **Plant tissues of uniform size are cut to identical length and then distributed equally in a graded series of solutions ranging from dilute (distilled water) to a molar concentration of solute in solution.**

- **The tissues are allowed to equilibrate in these solutions for one to two hours until all the cells are in equilibrium with the outside medium.**

- **The tissues lengths are re-determined and the difference between the final and initial length calculated.**

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.2 Linear Dimension (Length)

- **The change in percentage (%) of initial length is then plotted against the molarity of graded solutions.**
- **The water potential (Ψ) of the cells of the tissue is equal to that of the solution which causes no change in length.**

Limitations or disadvantages of method

1. **Destructive; plant tissue have to be removed from whole plant.**
2. **Long equilibrium time prevents frequent samplings.**
3. **Limited to availability of plant material.**
4. **Atmospheric conditions may not be the same in laboratory as that observed in the field.**

2.4 Measurement of Water Potential - *Methods*

2.4.3 Change in Density (Shardakov's method)

- **This method depends on the principle of displacement of liquids based on their density.**
- **The isotonic solution is that which causes no change in density after immersion of tissue in it.**
- **A dual range of graded sucrose solution is prepared.**
- **To one range a coloured dye is added. To the other the plant tissue is added.**
- **Tissues are allowed to equilibrate in the graded solutions for about 1 to 1½ hours after which they are removed.**

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.3 Change in Density (Shardakov's method)

- To each of the solutions a small drop from the corresponding coloured control solutions is introduced by a specially designed pipette.
- The water potential (Ψ) is determined by finding the isotonic solution in which the control drop does not rise or fall.

Limitations or disadvantages of method

1. Destructive; plant tissue have to be removed from whole plant.
2. Long equilibrium time prevents frequent samplings.
3. Limited to availability of plant material.
4. Atmospheric conditions may not be the same in laboratory as that observed in the field.

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.3 Change in Density (Shardakov's method)

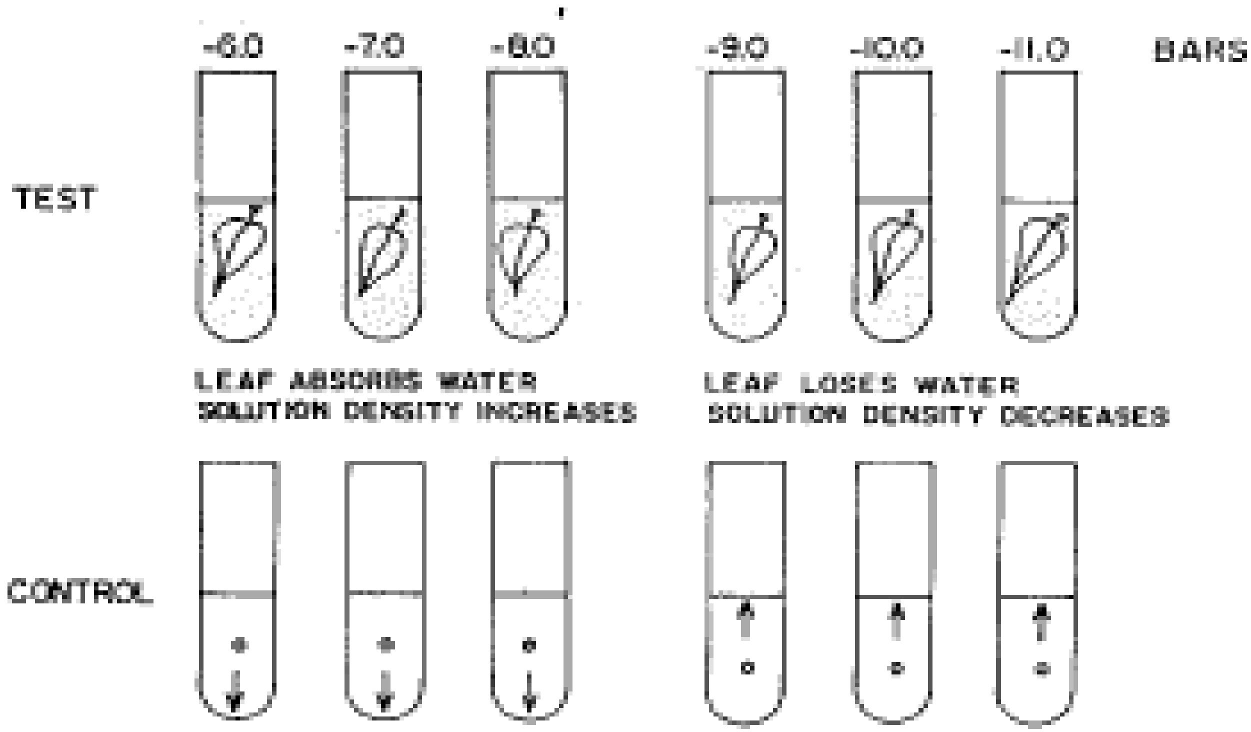


FIG. 1. Diagram representing dye method for measuring leaf water potential. The measured water potential is taken to be between the solutions in which the colored test solution drops rise and fall, i.e., —8.5 ± 0.5 bars.

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.4 Change in Refractive Index (RI)

- **This method depends on the principle of refraction (change in direction/the ability of light to pass through).**

- **The refractive index (RI) is measured quantitatively with a refractometer. The isotonic solution is that which causes no change in refractive index** (RI) **after immersion of tissue in it.**

- **A graded series of sucrose solution is prepared and their refractive index (RI) measured using a refractometer.**

- **Plant tissues are introduced into the range of solutions, covered and allowed to equilibrate for about 1 to 1½ hours.**

2.4 Measurement of Water Potential - *Methods*

2.4.4 Change in Refractive Index (RI)

- After this time **the tissues are removed and the refractive index (RI) of each solution re-determined**.
- **The ratio of initial/final refractometer readings are plotted against molarities of sucrose solutions**.
- **The water potential (Ψ) is determined by finding the isotonic solution in which there is no change in the refractive index** (RI).

Limitations or disadvantages of method as in gravimetric.

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.5 Pressure Bomb

- ❖ The pressure bomb technique for estimating xylem water tension was developed by Scholander *et al.* (1964/65).

- ❖ The leafy shoot or leaf petiole is quickly cut with a sharp scalpel and placed in a pressure chamber with the cut end of the petiole or stem just protruding from the chamber through a rubber gland which is used to seal the chamber.

- ❖ The pressure in the chamber is gradually increased by compressed air (nitrogen or inert gas) from a cylinder until the sap/water just returns to the severed ends of the xylem vessels.

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.5 Pressure Bomb

❖ The pressure required to **force water to the cut surface** corresponds to the water potential of the leaf.

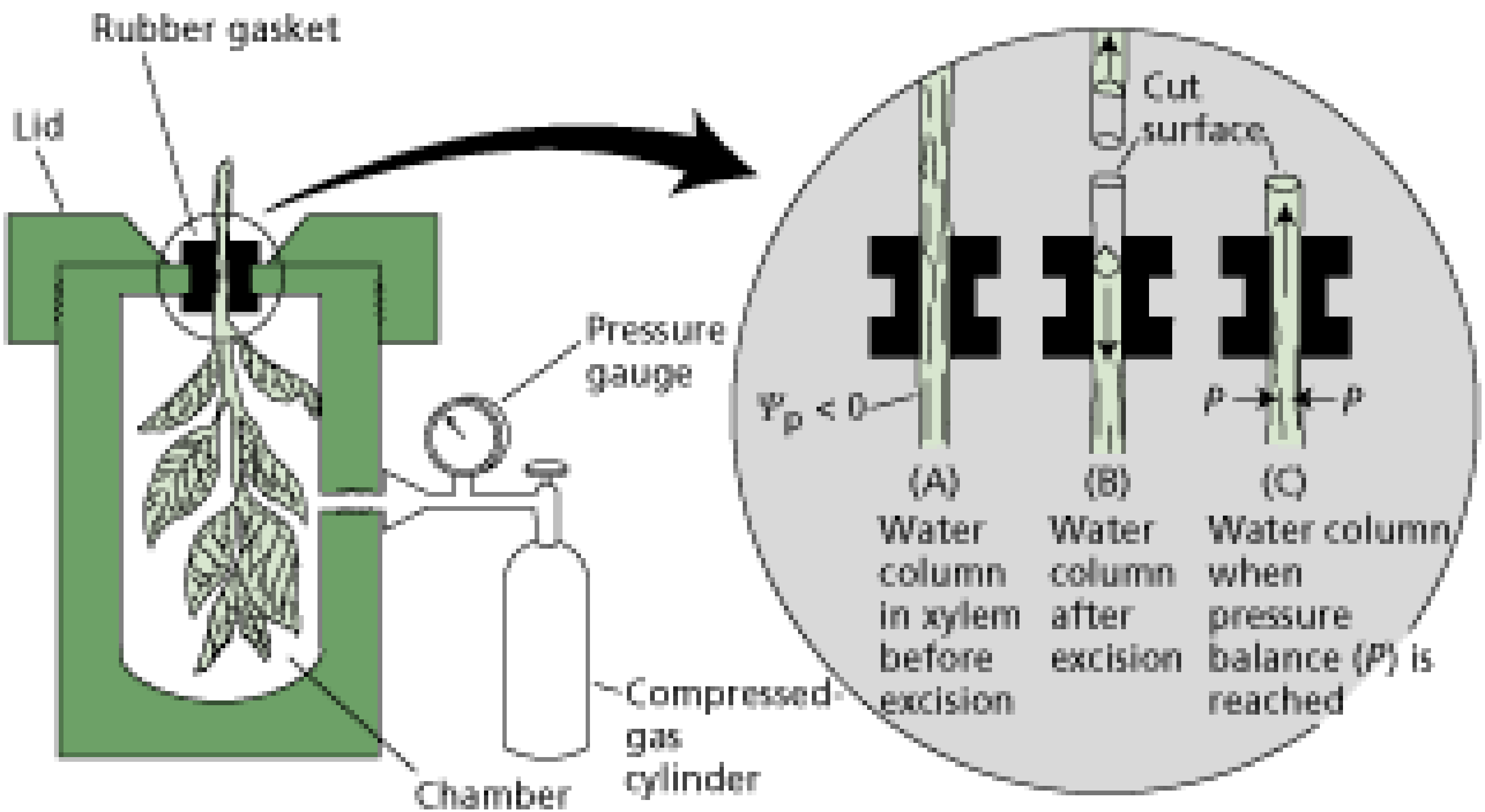
Advantages of method

1. **The pressure bomb technique is rapid and accurate.**
2. **It is insensitive to temperature.**
3. **Readings/values can be obtained quickly allowing a large number of specimen to be sampled.**

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.5 Pressure Bomb



2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.6 Thermocouple Psychrometry

- **Thermocouple psychrometry is the most widely used method of measuring plant water status. It's a non destructive field method.**
- **It can measure the water status of any plant part as well as soil or any substance containing water.**
- **The equipment is used for measuring/sensing temperature difference. The hydrometer consists of a wet and dry bulb thermometers.**
- **The water content of the sample is allowed to equilibrate with that of the air vapour.**
- **The greater the amount of water in the sample the longer the equilibration time.**

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.6 Thermocouple Psychrometry

- After equilibrium has been achieved, **the thermocouple is cooled below the dew point,** resulting in condensation of the air vapour to form a film of water.

- **The energy used to evaporate the condensed water corresponds to the water potential of air vapour and consequently that of the sample.**

- **The technique gives the most accurate measurements of water potential (Ψ).**

2.0 Concept of Water Potential *contd.*

2.4 Measurement of Water Potential - *Methods*

2.4.6 Thermocouple Psychrometry

- **The technique works over the entire range of water contents and, because it measures conditions in the gas phase, it does not require a continuous liquid phase for the measurement.**

- **The only requirement is that water should be able to evaporate from the sample to the air.**

- **The method uses only a small sample which is important for repeated measurements in the same plant or soil.**

3.0 Water Relations of Whole Plant

3.1 Composition of Water in Plants

- **Water** is the most abundant component of organisms. A cell in man contains approximately 80% water and the whole body about 60%.

- **In plants water constitute about 75 to 95% of the soft plant tissues, 50% of woody parts/tissues, about 85 to 95% of succulent parts and in water plants 95 to 98%.**

- **The absorption of water, its distribution between tissues and its retention are important aspects in the physiological functioning of land plants.**

- From the total amount of **water** absorbed by plants only about 2 to 5% is retained for growth and chemical reactions. The rest evaporates through the leaves by the process of transpiration.

3.0 Water Relations of Whole Plant

3.1 Composition of Water in Plants

Water composition of plants (which also reflects the plant water deficit) can be determined or described by two basic parameters.

- The **energy status** of the contained water, usually expressed as the total water potential.

- **Water content**; expressed as a percentage of dry weight and fresh weight.

3.0 Water Relations of Whole Plant

3.1 Composition of Water in Plants

The water content of plants can be measured in two ways:-

a) Direct Measurement of Water Content

- This is the direct quantitative assessment of a sample or samples representing all parts of the plant body.
- The water content of the sample(s) representing all parts of the plant body is directly quantitatively measured.
- The **total (fresh) weight** (**TW**) of the plant material is first determined and then oven dried at temperature between 80^{o}C to 90^{o}C until it reaches constant weight. Time will depend on the plant material used.
- The plant material is then cool and reweighed. The **dry weight** (**DW**) is subsequently determined.

3.0 Water Relations of Whole Plant

3.1 Composition of Water in Plants

a) Direct Measurement of Water Content

From the result obtained, the relative water content of the plant can be expressed as **percentages of fresh and dry weight**.

- **Percentage (%) FW** $= \dfrac{TW - DW}{TW} = \dfrac{FW}{TW} \times 100$

- **Percentage (%) DW** $= \dfrac{TW - FW}{TW} = \dfrac{DW}{TW} \times 100$

3.0 Water Relations of Whole Plant

3.1 Composition of Water in Plants

b) Water Content at Full Turgor

This approach consists simply in comparing water content of a sample immediately after collection with that after the same has been rendered fully turgid by allowing water uptake until water potential has risen to zero.

- **The cut discs of leaf tissues (using a cork borer and a rubber bung) are accurately weighed in closed specimen tube.**

- **They are then (floated) placed into distilled water in a covered petri dish for one hour.**

3.0 Water Relations of Whole Plant

3.1 Composition of Water in Plants

b) Water Content at Full Turgor

❖After this time the discs are then **surface dry and reweighed** and then dry for at least two hours in an oven at 80^{o}C to 90^{o}C and reweigh.

❖From the results obtained the **relative water content** (**RWC**) can be calculated using the formula:**-**

$$\mathbf{RWC = \frac{FW - DW}{(TW - DW)} \times 100}$$

Where **FW** is the fresh weight, **TW** is the turgid weight and **DW** is the dry weight.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

- Unlike animals, plants (specifically land plants) are confronted with an enormous challenge in obtaining and retaining water, since they lack mobility.

- They are nonetheless active organisms with many dynamic processes occurring within (each part of) the plant e.g. photosynthesis, storage of manufactured products, transport, etc.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.1 Plant Absorbing Transport Systems

- The roots and leaves are the main absorbing organs of plants.

- Roots absorb water and dissolved mineral salts from the soil and the leaves take in oxygen (O_2) and carbon dioxide (CO_2) from the atmosphere.

- **The roots have been structured so that they have ready access to soil water.**

- **The production of root hairs in enormous numbers helps the plant in absorption.**

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.1 Plant Absorbing Transport Systems

- The leaves found in the above ground area are normally surrounded by relatively drier air.

- The conducting or vascular tissues of higher plants are the xylem and the phloem (each with component cell types).

- Water and mineral transport occur in the xylem (tracheids and vessels).

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.2 Absorption

Uptake of water by the roots from the soil

- **Water and mineral salts (inorganic salts) in a state of very dilute solutions are absorbed by unicellular root hairs which penetrates the soil.**

- The maximum absorption of soil water takes place through the root hairs and also through the zone of **cell enlargement**, whilst the maximum absorption of inorganic salts takes place through the zone of **cell division**.

3.2 The Ascent of Sap

3.2.2 Absorption

Soil water occurs in two forms:-

i. Capillary water

ii. Hygroscopic water

- **Capillary Water**: This is soil water available for absorption by roots. The water can be found surrounding each soil particle as a thin or sometimes thick film of water, loosely held to it by capillary force.

- **Hygroscopic Water**: Occur as an extremely thin film of water on the surface of soil particles held by the force of imbibition. It is very tightly held by soil particles, the root hairs are unable to dislodge (remove) it. Thus, hygroscopic water is not made available to the plant.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.2 Absorption

Uptake of water by the roots from the soil

❖ Water is drawn or (taken up or absorbed) into the root hairs mainly by the process of osmosis (which can also be aided by active transport).

❖ The concentration of the vascular sap in the root hairs is greater than that of the soil water as a result water is drawn across the cellulose wall through the semi permeable protoplast into the vacuole.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

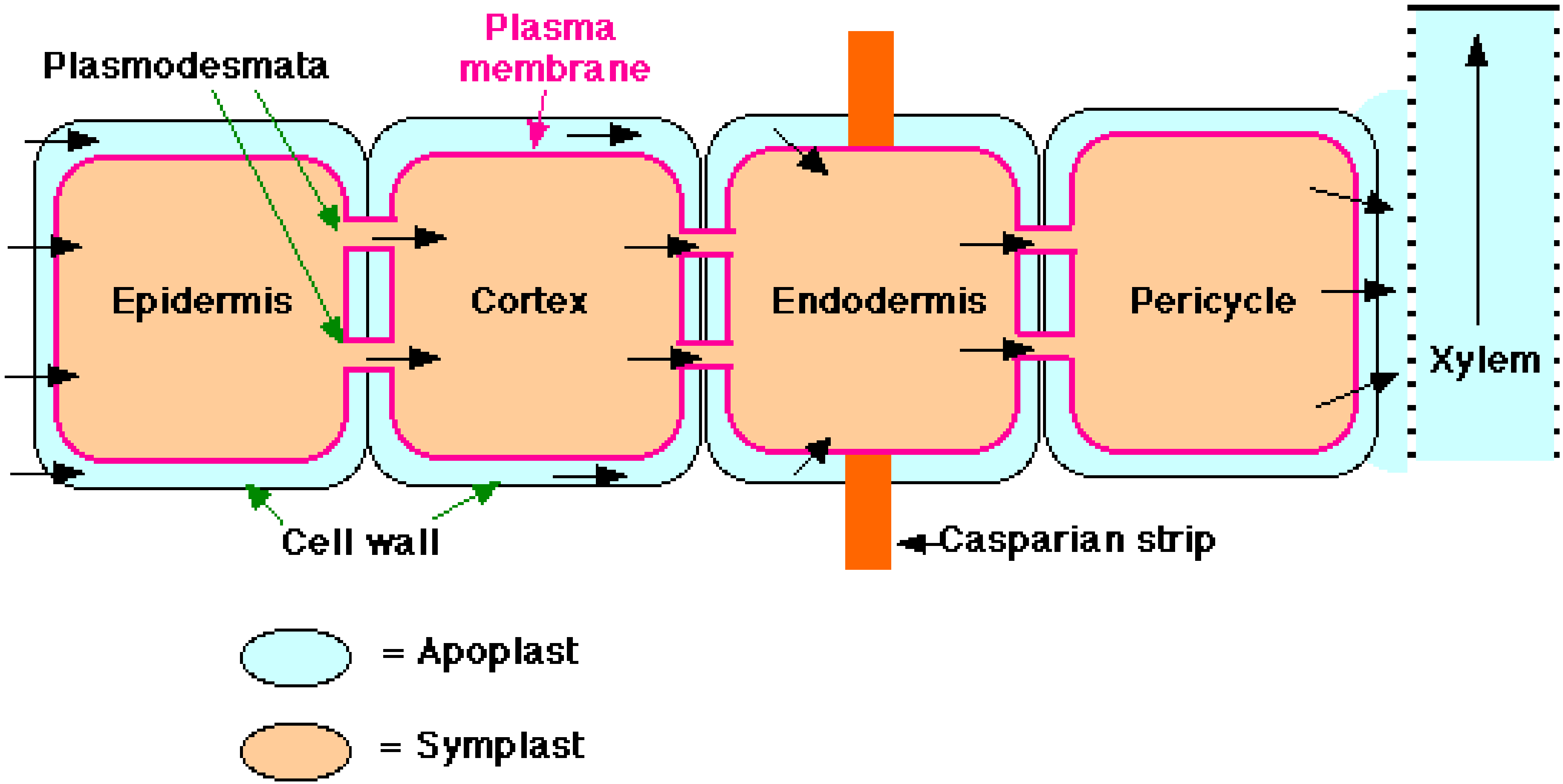
3.2.2 Absorption

Water and dissolved minerals entering the plant through the root hairs (through the parenchymatous cells of the cortex into the vascular tissues) can follow **three** (3) possible pathways.

- The **Apoplast**: is the pathway (of water and dissolved minerals movement) along and between cell walls, through intercellular spaces between them.
- The **Symplast**: is the pathway (of water and dissolved minerals movement) through the cytoplasm, from cell to cell via the plasmodesmata strands. It is a continuum of cell linked via plasmodesmata.
- The **Vacuolar**: is the pathway (of water and dissolved minerals movement) through the sap vacuoles, from one vacuole to the next by osmosis.

3.2 The Ascent of Sap

3.2.2 Absorption



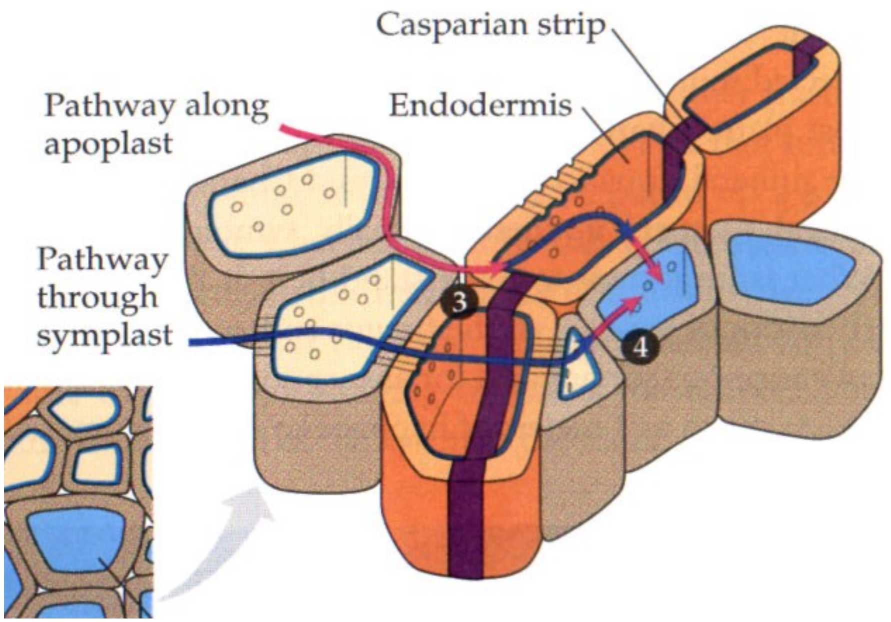
Transverse section of cells of root cortex showing pathways of ion movement in the cytoplasm

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.2 Absorption

Primarily water uptake occurs by osmosis along a water potential gradient from the soil solution into the parenchyma cells of the (via the root hairs) cortex.



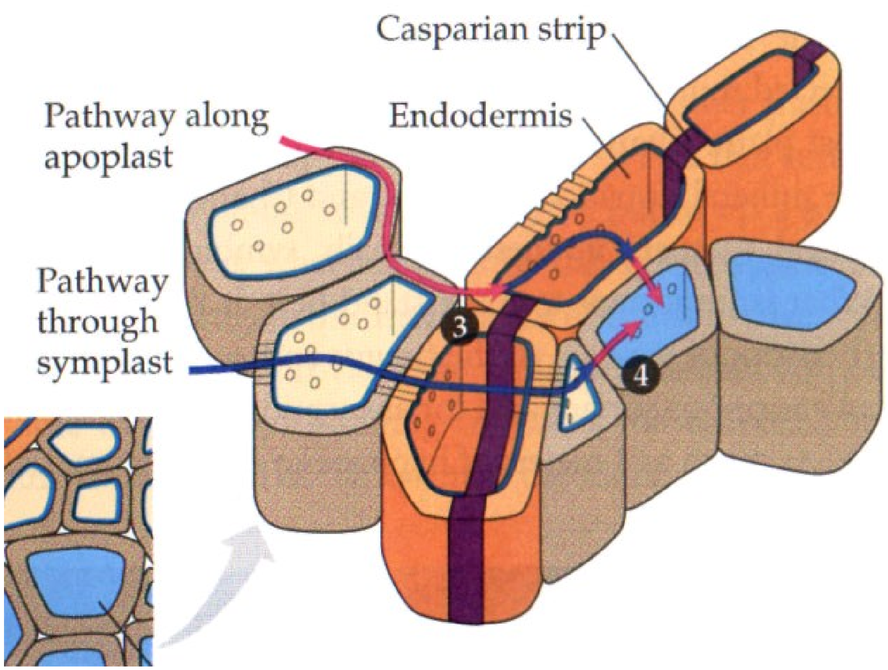
- In its movement towards the vascular system (xylem) through the cortex, water molecules from dilute soil solution can diffuse through the (cell walls and intercellular spaces) **apoplast** until they reach the endodermis, **OR**

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.2 Absorption

- The water molecules can diffuse through the plasmodesmata (the symplast) interconnecting the cytoplasm of cells through the endodermis into the xylem (via the pericycle),**OR**



- **Water molecules can be drawn from cell vacuole to cell vacuole by osmosis through the endodermis into the xylem (via the pericycle).**

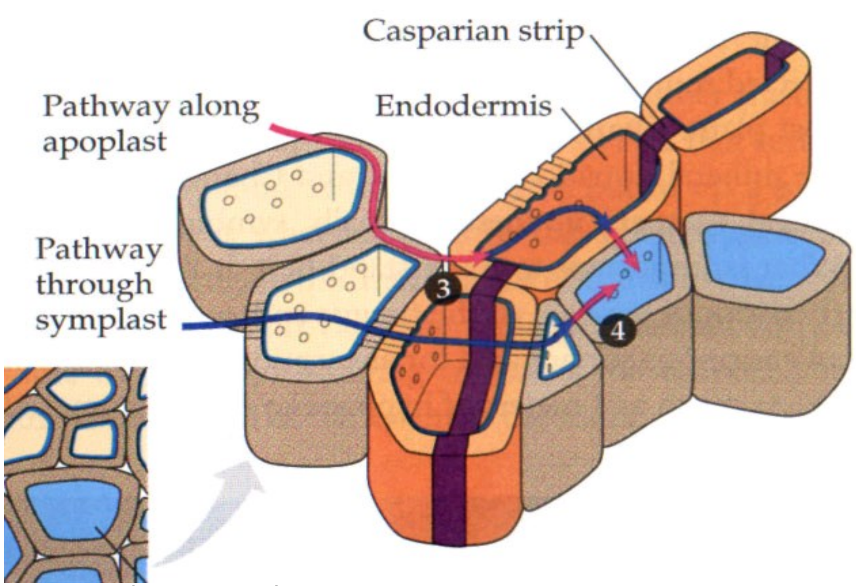
- **In the roots unlike the stem the endodermis is a specialized cylinder of thickened cell wall bands.**

3.2 The Ascent of Sap

3.2.2 Absorption

- Further movement of water via the apoplastic pathways into the xylem through the endodermis is prevented by the **casparian strip**. This is a water proof band or layer of suberin (and in some instances lignin) impregnated on the radial and transverse cell walls (top, bottom and sides) of the endodermis.

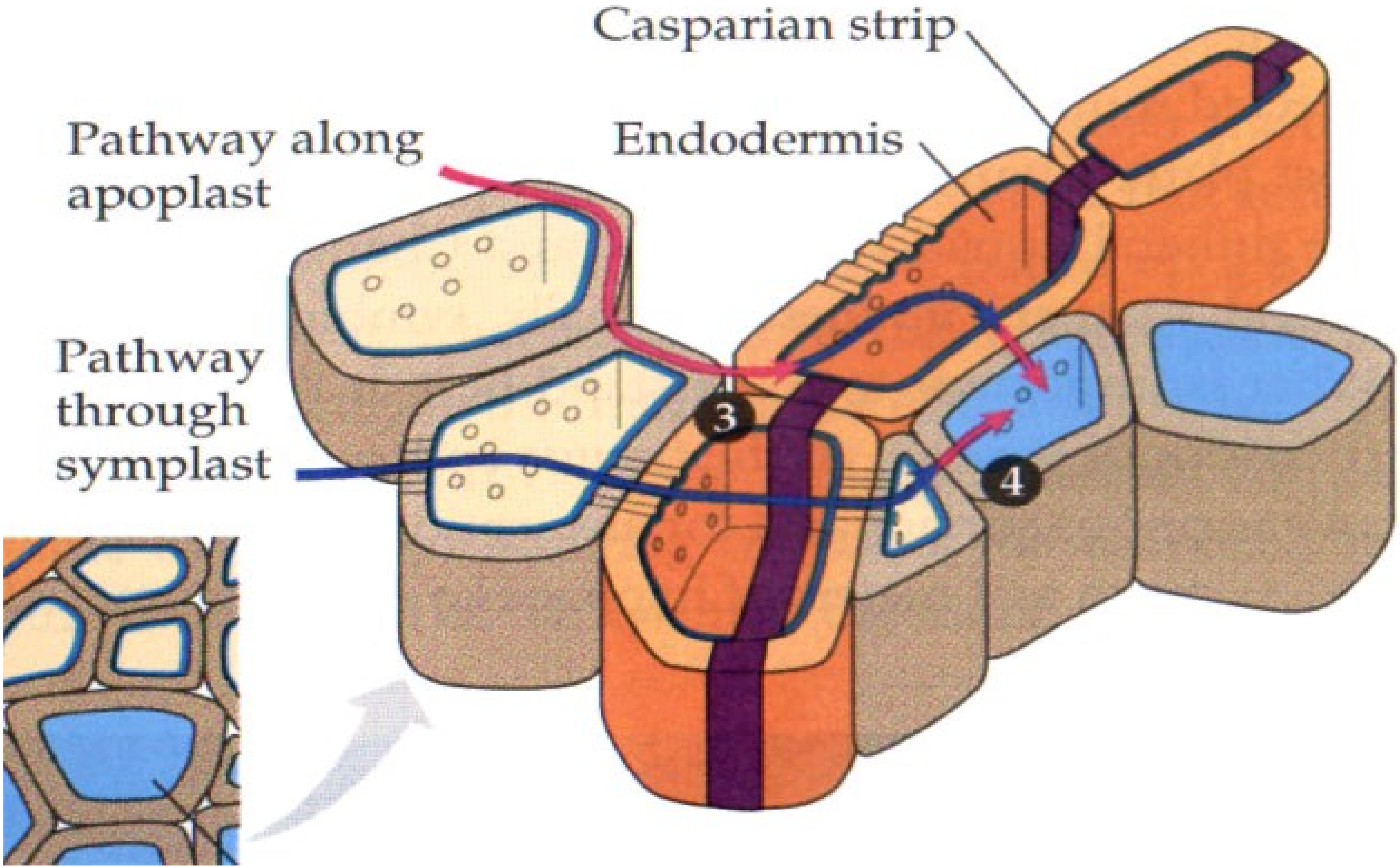
- The movement of water is therefore directed to the tangential walls of the endodermis and into the cytoplasm of these cells and hence the symplast.



- The presence of the casparian strip on the walls of the endodermis regulates the movement of water and minerals into the stele.
- Once inside the cytoplasm of the endodermis cell water moves symplastically into the living cells of the pericycle, the outer most layer of the stele.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap



3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction

Movement of water through the plant

- **Water moves (diffuses) into the conducting cells of the xylem (vessels) from the root cortical cells by the force of transpiration pull or by pumping under pressure.**

Root Pressure

- **Pumping under pressure can be referred to as root pressure. Root pressure is defined as the pressure under which water passes from the living cells of the root cortex into the xylem.**

- **Root pressure is also regarded (as the outcome of) an osmotic mechanism, where water from the soil moves through the root tissues along a gradient of water potential (Ψ).**

3.2 The Ascent of Sap

3.2.3 Conduction

- **As water enters the root cortical cells (by the process of osmosis) it gradually accumulates making the cells to become turgid.**

- **This movement of water from one adjacent cell to another naturally creates a pumping action of considerable pressure forcing water into the xylem vessels.**

- Root pressure can be demonstrated by decapitating (severing) the stem of a plant above ground.

- The cut end of the stump will exude a large amount (quantity) of sap, slowly i.e. **Bleeding**, but for a long period (time), suggesting that there is a force pushing water up the stem from the roots.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction

- The effects of root pressure can also be observed by the process of **guttation**.

- Guttation is the excretion of drops of water by plants through the vein-endings in leaf margins or at special points known as ***hydathodes***, water pores or stomata, occurring usually under condition of high humidity and its due to pressure built up within the xylem by osmotic absorption of water by roots.

(*Hydathodes: are specialize structures through which exudation of water takes place in liquid form. They are found mainly in aquatic and herbaceous plants in moist places. They occur at apices, veins at the tips of leaves or on their margins*).

3.2 The Ascent of Sap

3.2.3 Conduction

❖**Guttation -** the effects of root pressure.

(*Excretion of drops of water by plants form at apices, veins at the tips of leaves or on their margins or at special points known as hydathodes*).

3.2 The Ascent of Sap

3.2.3 Conduction

- When a plant is under root pressure it can be assumed that all tissues have more than adequate supply of water in the apoplast so that all the cells can be become fully turgid.

- A positive hydrostatic pressure thus develops in the xylem and causes water to be forced out through the leaf margins.

- Root pressure would persist (applied) only when water yielding capacity of soil is high, underlying the fact that the quantity of water that can be moved by root pressure is limited.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction

- In practice root pressure varies between 1 to 2 atmospheres and may be adequate to force up water in herbs, shrubs and low trees up to a maximum height of 10 metres.

- However, root pressure is not enough to send sap to the top of high trees. A pressure of 10 to 20 atmospheres is required to move sap to the top of high trees of about 90 metres.

- The process is also slow and cannot keep pace with water loss of transpiration.

- Further at high temperature rate, root pressure is at its lowest and cannot be use to account for water movement in many plants at certain times of the year.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

1. Temperature:

- **The temperature of the soil and atmosphere affects water uptake and movement.**
- **Soil temperature affects root growth and permeability (both decrease at low temperature).**
- **At low temperature viscosity of water increases resulting in a reduction of water uptake via the root.**
- **In the atmosphere temperature increase will increase transpiration rate. The higher the temperature the faster the evaporation.**

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

Q_{10} - Temperature coefficient of a process

- **It has been demonstrated that there is a specific effect of change in temperature on the rate of a process.**
- **In most cases, a rise in temperature will produce an increase in the rate of a process and a fall in temperature will bring about a decrease in rate.**
- **In the investigation of a particular process the interval through which temperature change is effected is defined.**
- **In most studies an interval of 10°C is used, hence the temperature coefficient of the process is termed the Q_{10} of that process.**

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

Q_{10} - Temperature coefficient of a process

The measurement of the Q_{10} of a process is important in physiological studies as it enables us to obtain some information concerning the fundamental nature of that process.

For instance:-

- ✓ **The Q_{10} of a chemical/biological process is usually 2 – 3, that is the rate of reaction doubles or trebles for every 10^oC rise in temperature.**
- ✓ **The Q_{10} of a physical process e.g. diffusion is in the range of 1.2 to 1.6.**
- ✓ **The Q_{10} of a photochemical process is 1 that is unaffected by temperature.**

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

Q_{10} - Temperature coefficient of a process

- **Most Q_{10} are positive but in some processes a negative Q_{10} can be observed.**

- **An example is the denature of enzyme proteins.**
- **The rate of an enzyme catalysed reaction will generally decline with an increase of temperature from 50°C to 60°C.**

$$Q_{10} = (k2/k1)^{10/(T2-T1)} = \log Q_{10} = (10/T2-T1) \log K2/K1$$

T1 = lower temperature **K1 = rate at T1**

T2 = higher temperature **K2 = rate T2**

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

2. Aeration/Oxygen

- **The roots must receive adequate supply of oxygen from the soil for respiration and growth.**
- **Lack of oxygen (high concentration of CO_2) decreases permeability of roots to water.**
- **Anoxia – completely lacking O_2.**
- **Hypoxia – partially lacking O_2.**

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

3. Soil Moisture

- **The amount of water a soil can hold depends on the type of soil.**
- **Soils with fine particles can hold more water than coarse soils.**
- **Soils containing much more water against that which it can hold normally under water gravity is said to be at field capacity.**
- **Water potential of soil at field capacity is very high (almost zero) therefore uptake by plants occurs freely.**

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

3. Soil Moisture *contd.*

- Reduction in water content of soil lowers the water potential of the soil.

- Further reduction leads to soil moisture stress wherein the plant (can no longer) is unable to obtain water to compensate (counteract) transpiration loss.

- Wilting sets in and the soil moisture is said to have reached the **permanent wilting point** (PWP).

3.2.3 Conduction - *Conditions affecting root pressure*

4. Soil Salinity

- Concentration of solutes in the soil greatly interferes with the absorption of water.

- As soil water is a solution of ions the plant has to absorb water from soil against osmotic (solute) forces.

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

5. Relative Humidity

- This is the degree to which the atmosphere is saturated.
- The relative humidity (RH) determines the saturation deficit that is the difference between the inside and outside of leaf.
- The lower the relative humidity of the surrounding atmosphere the greater will be the saturation deficit and the faster water vapour will escape through the stomata.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

5. Relative Humidity *contd.*

- The amount of water in the air is given by absolute humidity, typically measured in grams per cubic meter.

- Relative humidity is a ratio of how much water vapor is in a given volume of air compared with the amount of water vapor that would saturate the air at a given temperature and pressure.

- Because it's a ratio, relative humidity is given as a percentage.

- When the air is saturated and contains the maximum amount of water vapor, the relative humidity is 100%.

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

6. Light

- Light intensity affects evaporation indirectly.
- It causes the stomata to open, thereby increasing water loss from the plant.
- Stomata generally open in the light and shut in darkness.

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

7. Stomata

- The number and the degree of opening of stomata is often the most important single factor controlling the rate of transpiration.
- Transpiration is most rapid when stomata are fully open and slowest when fully closed.
- Where there is a mid-day closure of stomata, this is always accompanied by a reduction of transpiration rate.

3.2 The Ascent of Sap

3.2.3 Conduction - *Conditions affecting root pressure*

7. Stomata *contd*.

- The transpiration of leaves with stomata confined to the lower surface shows a much greater reduction of rate when the lower surface is vaselined than when the upper surface is vaselined.
- Stomata are most abundant in the lower epidermis of the dorsiventral leaf.
- In isobilateral and centric leaves the stomata are more or less evenly distributed on all sides.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration Pull

- **After going through the endodermis via the symplast/vacuolar pathways into the pericycle water enters the xylem through the cell walls due to cohesion (apoplast) and osmosis along a water potential gradient from the symplast/vacuolar pathways.**

- **Once water is in the xylem of the stele its movement upward in the plant is driven by the pull of transpiration (cause by a state of tension or negative pressure in the xylem vessels) and the evaporation of water from the leaf surface.**

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration Pull

The continuous stream of water column in the vessels is caused and maintained by:

- The strong force of attraction (**Cohesion**) between water molecules caused by hydrogen bonding,
- **Adhesion** (i.e. attractive force between molecules of water and the inside surfaces of walls of vessels elements and tracheids) and the evaporation of water from the leaf surface,
- **Osmosis** in the mesophyll cells of the leaf and by
- The **evaporation** of water from the leaf surface.

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration Pull

- **The adhesion of water to the cellulose walls provides a continuous source of water that evaporate into the intercellular spaces of the leaf and transpire through the stomata.**
- The cohesive force is so strong that any force or pull on one water molecule acts on all of them forming a long continuous column in the vessels, extending from the root to the leaf without any break or air bubbles. **Any break in continuity is maintained by the vapour phase**.
- Water leaves the xylem via the vessels into the leaf tissues through the apoplast due to cohesion and through the symplast and vacuolar by osmosis along a water potential gradient.

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration Pull

- Water evaporate from the cellulose cell walls of cells of the palisade and spongy mesophylls into the sub-stomatal chamber.

- Water diffuse from the sub-stomatal chamber into the atmosphere. The rate of movement is influenced by factors which changes the water potential gradient between chamber and the atmosphere.

- This mechanism of water movement in plants is referred to as the **Cohesion-Adhesion theory** of transpiration.

3.0 Water Relations of Whole Plant

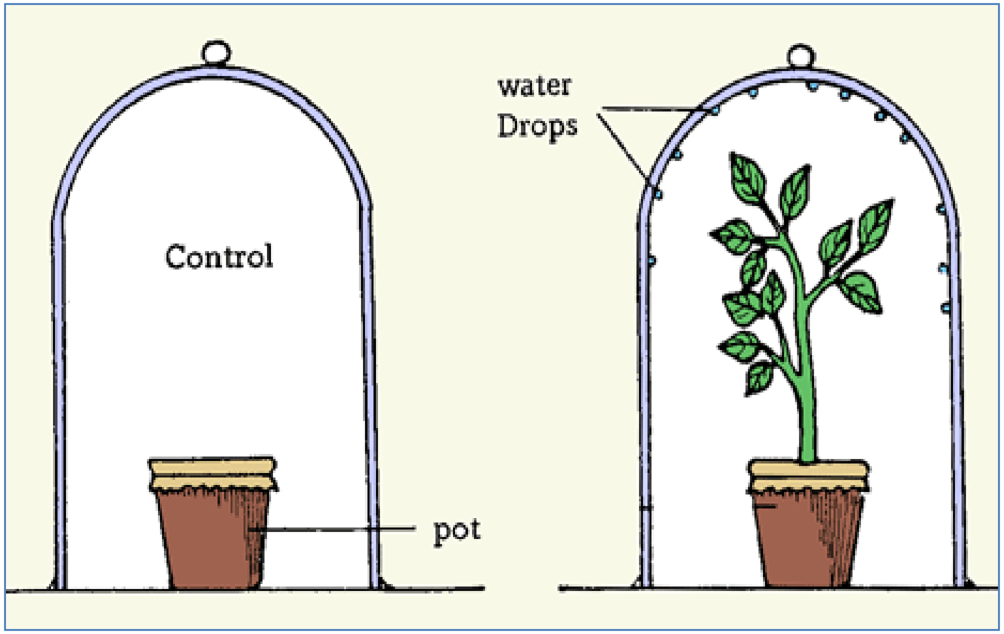
3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration Pull

Demonstration to show that water vapour is given off by plants.

- A covered potted plant, with soil covered with polythene, as shown is left outside the laboratory.
- A control experiment is set up with no plant.



3.0 Water Relations of Whole Plant

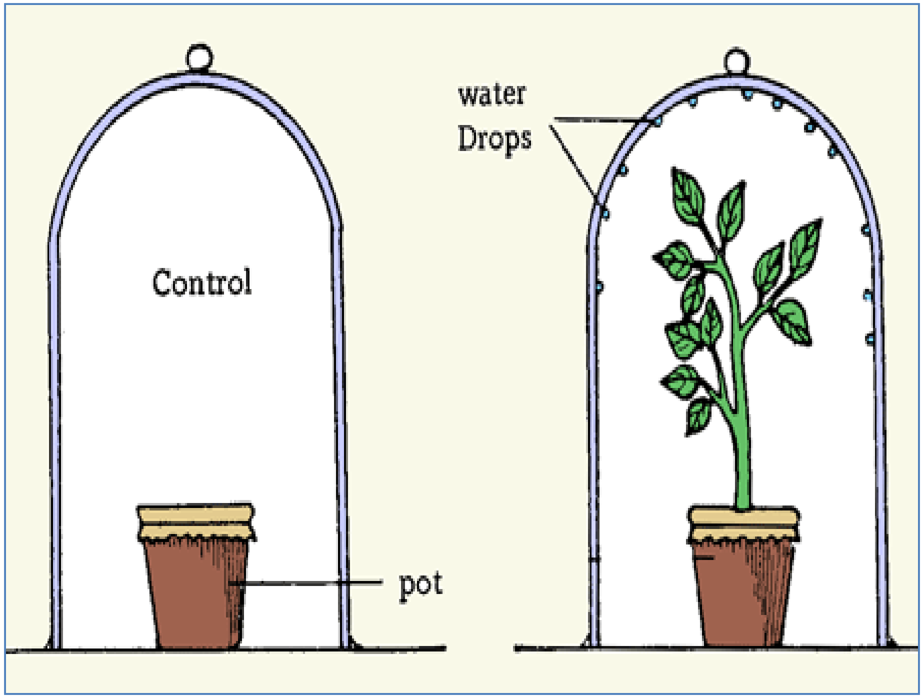
3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration Pull

Demonstration to show that water vapour is given off by plants.

- **After an hour, drops of colourless liquid are seen inside the bell-jar with the plant.**
- **To show that these drops are water, touch them with anhydrous copper sulphate (white) and its colour changes to blue.**
- **No drops of water are found in the control experiment where there was no plant.**



3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration Pull

Demonstration to show that water vapour is given off by plants.

- The behaviour of the stomata and the rate of transpiration are determined by environmental factors.

- Transpiration exerts a force against that of gravity, and this is known as transpiration pull, it enables water to be absorbed.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration

Is the **loss of water vapour from the internal tissues of living plants**, **through the aerial parts, mainly the leaves**, after its been absorbed from the soil solution.

- The vapour loss is mainly through the stomata.
- Stomatal transpiration constitute 70% and about 10% go through the cuticle known as cuticular transpiration.
- Quantitatively transpiration can be demonstrated by measuring either the rate at which the plant **lose water** or the rate at which it **takes up water**.

3.0 Water Relations of Whole Plant

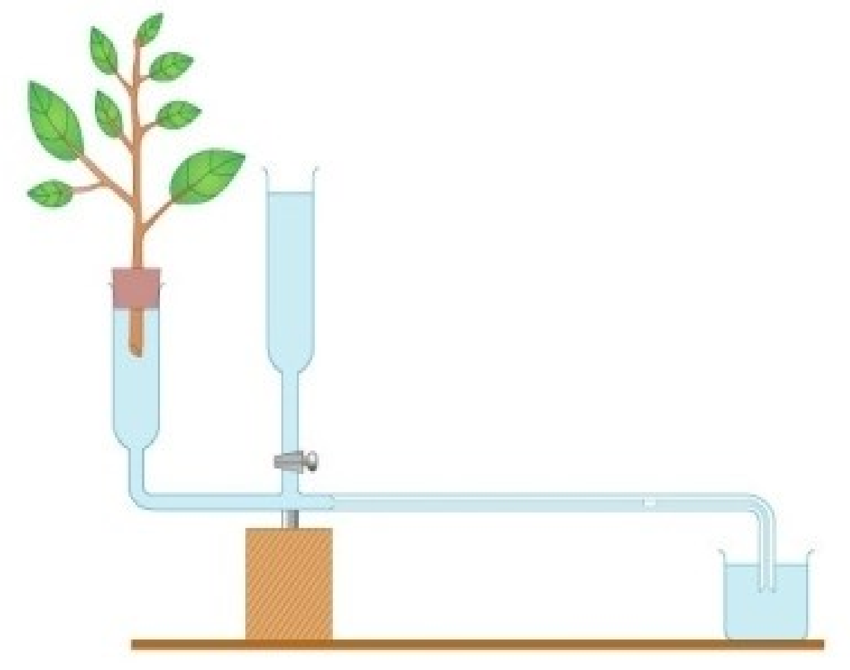
3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration *contd.*

- The **Potometer** is used to measured **water uptake**; with the **assumption that water uptake is equal to water loss**.

- The distance the water level drops in the graduated tube is measured over a length of time.
- It is assumed that this drop in water level is due to the shoot taking in water which is necessary to replace an equal volume of water lost by transpiration.



3.0 Water Relations of Whole Plant

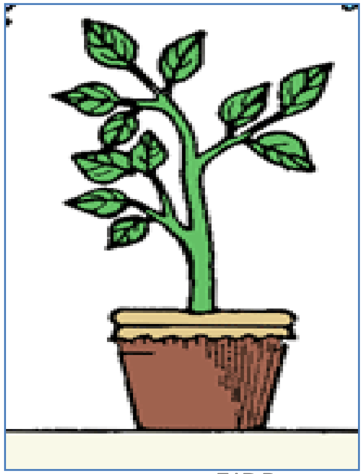
3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration *contd.*

- Directly, transpiration can be demonstrated by measuring **weight loss**.
- That is by weighing well watered potted plants and measuring weight changes over a period of time.
- This is on the assumption that weight loss is due **only to evaporation** of water.

- Water is prevented from evaporating from the soil by covering the whole pot in a polythene bag.



- Changes in the rate of transpiration are deter-mined by recording the weight at intervals and plotting the results on a graph.

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration *contd.*

- Transpiration provides most of the energy for water movement through land plants since it sets up a water potential gradient.

- The difference in water potential between the leaf and the atmosphere is very steep (sharp change) caused by the differences in temperature and water vapour concentration or relative humidity.

- The driving force of transpiration is large and often constant.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Transpiration *contd.*

- The change in water vapour in transpiration is therefore determine by the outward vapour diffusion or **diffusive resistance (R)**.
- At constant leaf temperature the relationship between the water vapour in transpiration and resistance to outward vapour diffusion (diffusive resistance) is $\mathbf{J_{wv} = \Delta C/R}$
- Where $\mathbf{\Delta C}$ is the difference in water vapour concentration inside and outside a leaf.
- If temperature is not constant then $\mathbf{\Delta C}$ is replaced by $\Delta\Psi_{\mathbf{wv}}$, hence $\mathbf{J_{wv}} = \Delta\Psi_{\mathbf{wv}}\mathbf{/R}$.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd.*

Significance of transpiration:

- **Absorption of water**

  Transpiration influences the rate of absorption of water from the soil.

- **Water movement**

  By transpiration, water moves upwards and as it passes into the cell vacuoles, it makes the cells turgid. This gives form and shape to cells and plant as a whole.

- **Mineral salt transport**

  The water stream moving upwards carries dissolved minerals with it. Transpiration also helps in distributing these minerals throughout the plant.

- **Cooling**

  The evaporation of water during transpiration cools the leaves.

- **Protection from heat injury**

  Some plants like cacti, retain water by reducing transpiration. This saves the plants from high temperatures and strong sunlight.

3.0 Water Relations of Whole Plant

3.2 The Ascent of Sap

3.2.3 Conduction – Water movement in plant *contd*.

Assignments

Write short notes on:

a) *Factors affecting the rate of transpiration.*

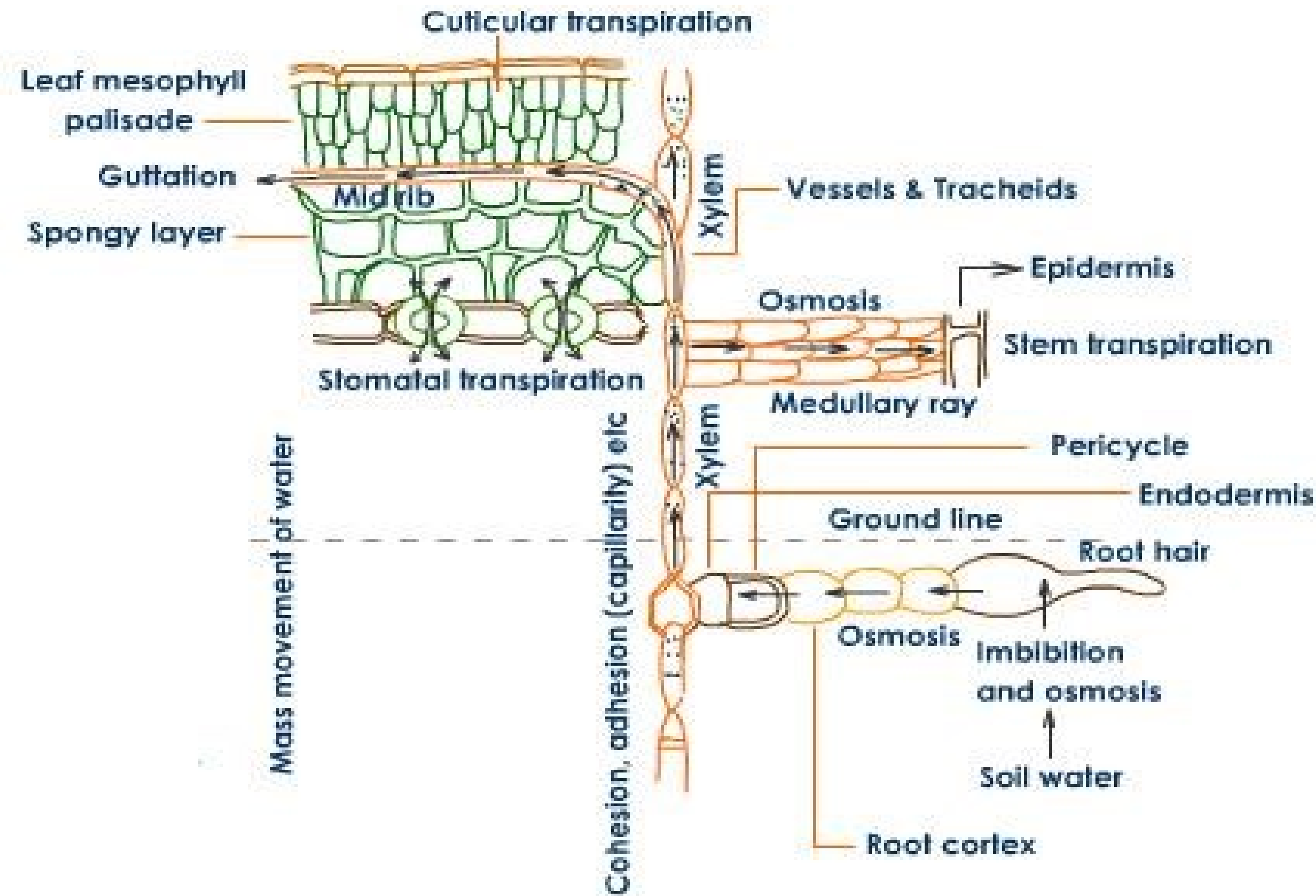
1. Temperature
2. Relative humidity
3. Wind
5. Soil water
6. Light
7. Stomata

b) *Plant adaptations to reduce excessive transpiration.*

1. Anatomical
2. Morphological

c) *Transpiration: its importance and necessity*.

3.2 Water path through the plant



3.0 Water Relations of Whole Plant

3.3 Physiology of the Stomata

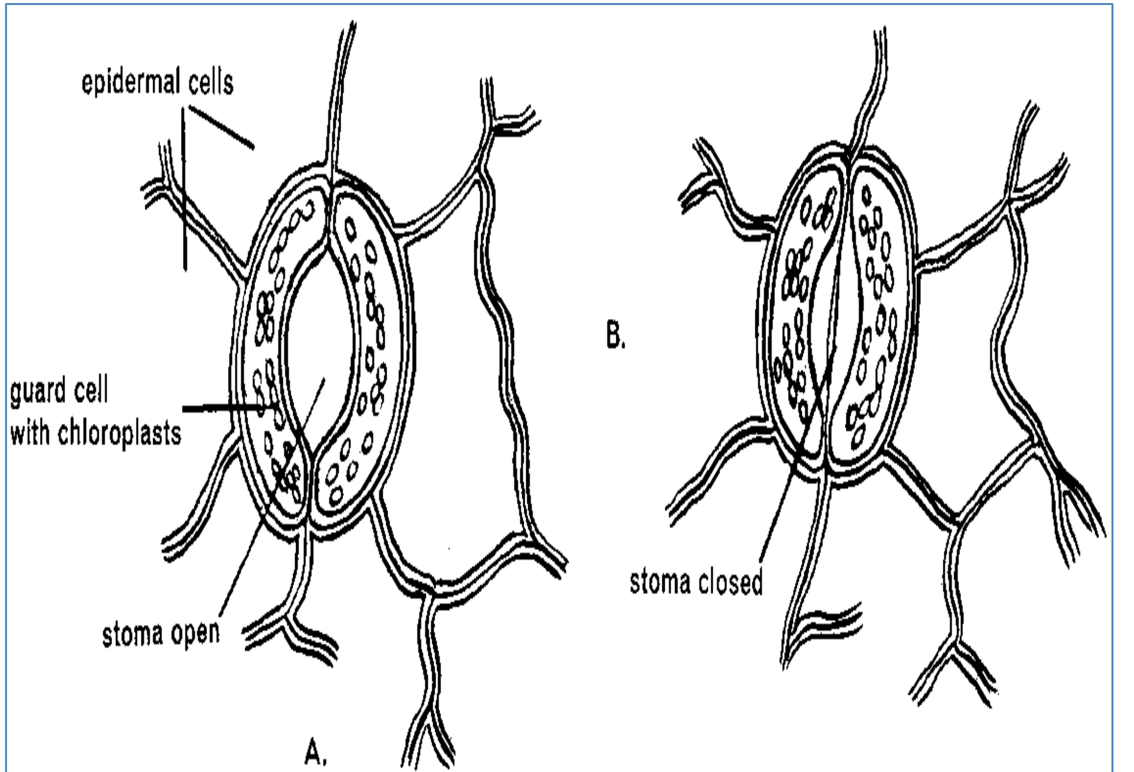
- **The stomata represent an important adaptation to life in a terrestrial environment.**
- **The action of the guard cells regulates the rate of water lost through transpiration and at the same time regulates the rate of photosynthesis by controlling the CO_2 uptake.**
- **Stomata are found in the aerial parts of the plant organs, but are most frequent on leaves and young stems.**
- **Each stoma consists of a pore surrounded by two kidney-shaped guard cells and additional epidermal cells referred to as subsidiary cells which may be associated with them.**
- **The whole guard cells plus subsidiary cells is called stomatal complex.**

3.0 Water Relations of Whole Plant

3.3 Physiology of the Stomata

- **Each guard cell has an unevenly thickened walls.**
- **The walls of the guard cells that border the stoma pore are thicker and less elastic than the thinner outer walls.**

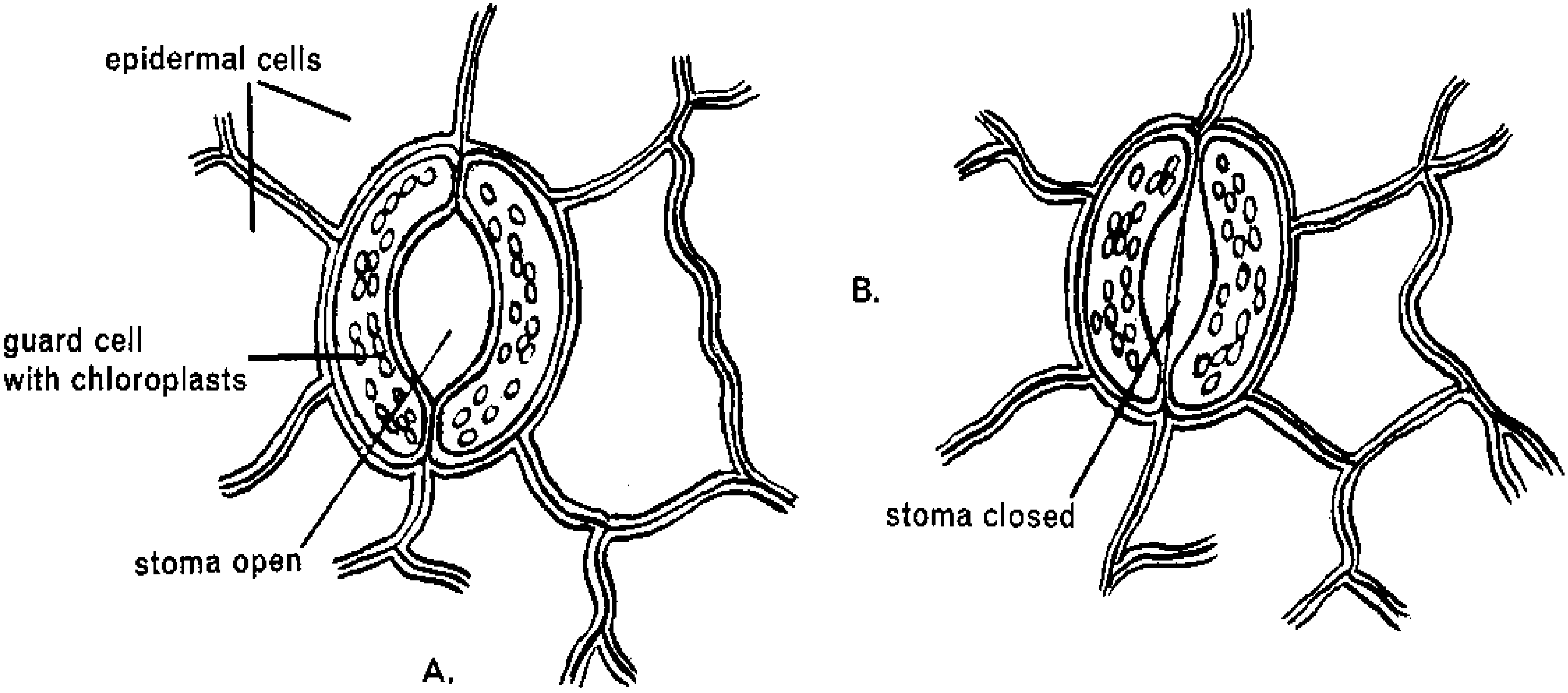
- **There are no symplastic (no plasmodesmata) connection between the subsidiary cells and the guard cells.**
- **The adjacent subsidiary cells also do not have the chloroplast or dense cytoplasm of guard cells.**



A. and B. SURFACE VIEW OF GUARD CELLS AND STOMA

3.3 Physiology of the Stomata

- **There are no symplastic (no plasmodesmata) connection between the subsidiary cells (special epidermal cells) and the guard cells.**



A. and B. SURFACE VIEW OF GUARD CELLS AND STOMA

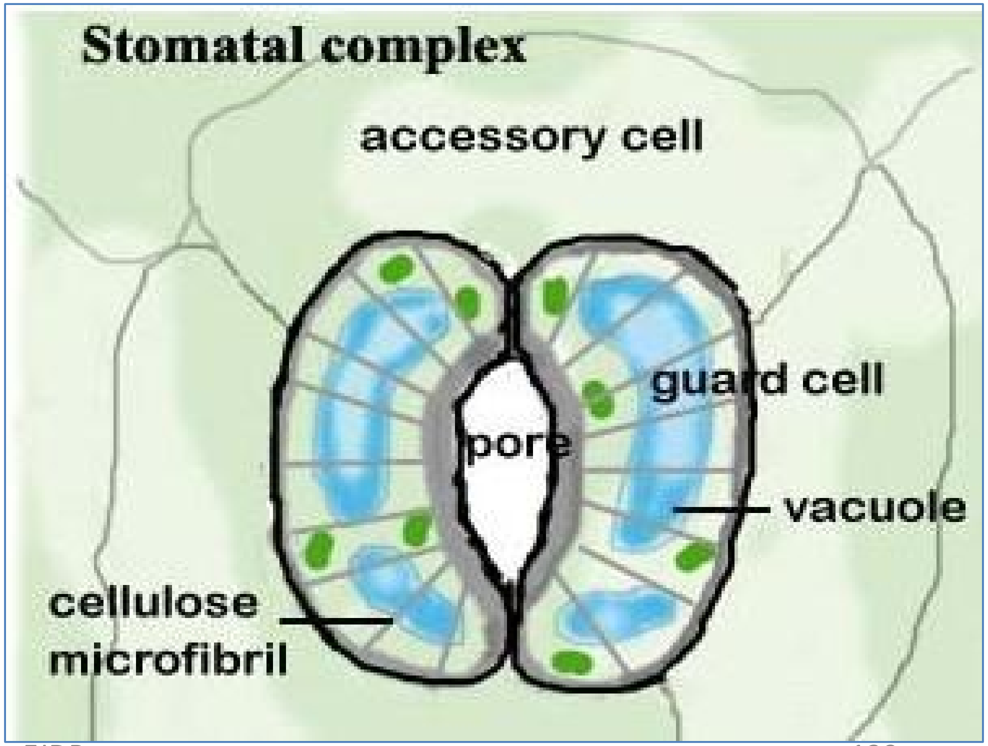
3.3 Physiology of the Stomata

Mechanisms of Stomata Opening

- Changes in turgor in the guard cells regulates the opening and closing of the stomata.

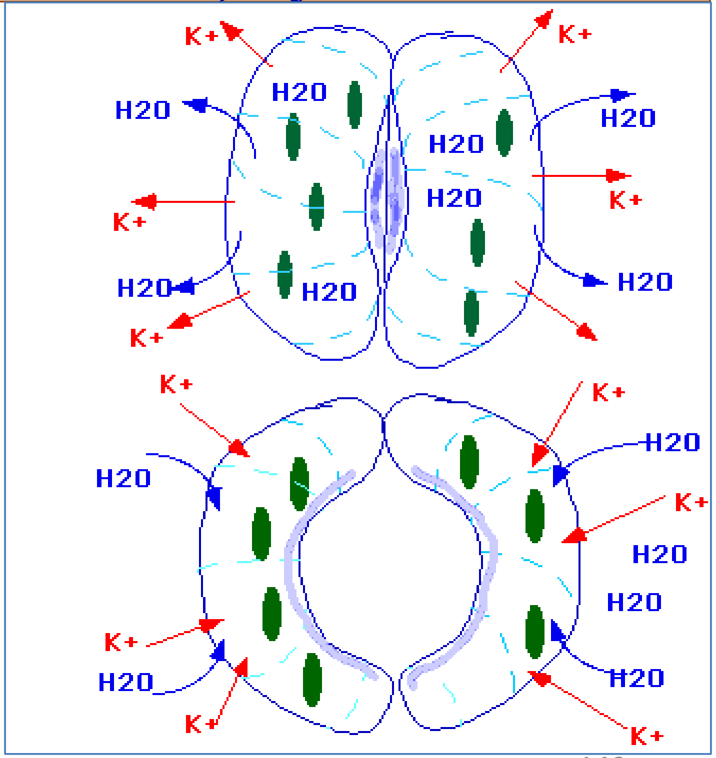
- When guard cells become turgid they expand outwards due to the radial orientation of **cellulose microfibrils**.

- This outward expansion of the guard cells **opens the stomata**.



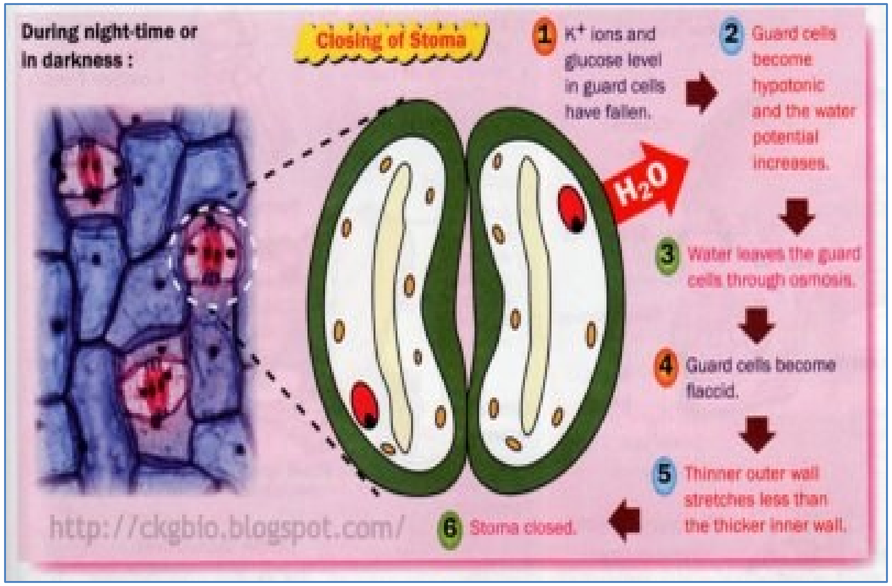
3.3 Physiology of the Stomata

- The **mechanism causing the stomata action** is mainly achieved by the **active transport of ions** (principally Potassium K^+) into the guard cells from the neighbouring epidermal cells.
- **As a result the solute potential, and thus their water potential, are altered causing water to move in (into guard cells) by osmosis.**
- **The uptake of K^+ is activated by the active pumping of proton (H^+) out of the guard cells energize/power by ATP (Adenosine triphosphate).**
- An electrochemical gradient develops (inside of the guard cells is negative with respect to outside) so that K^+ can flow passively through K^+ channels in the plasmalemma.

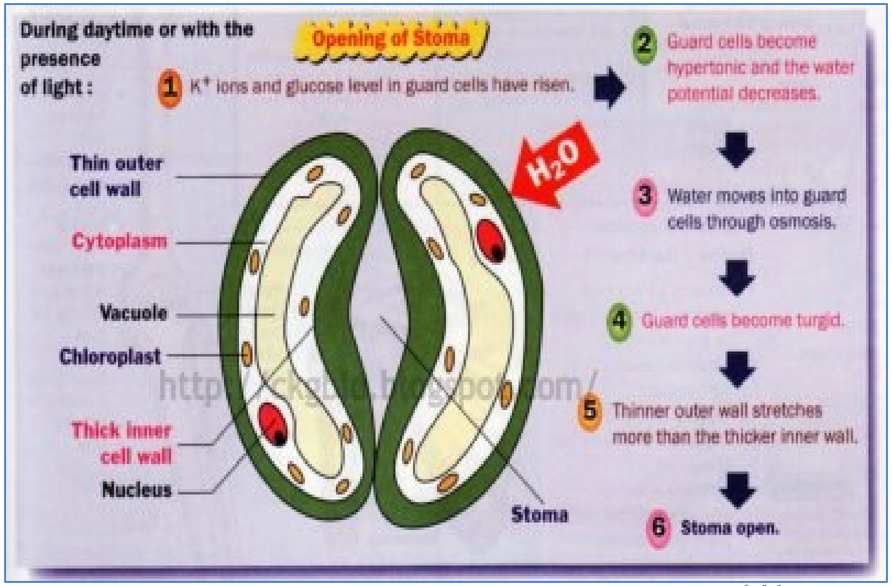


3.3 Physiology of the Stomata

- Stomata would close when guard cells are flaccid because water has been lost to the apoplast system of the epidermis.
- Reason: [K^+] in the guard cells has fallen/decrease. High water potential thus allow water to leave guard cells.



- Stomata would open when guard cells are turgid because water has been gained from the apoplast system of the epidermis.
- Reason: [K^+] in the guard cells has risen/increase. Low water potential thus allow water to enter guard cells.

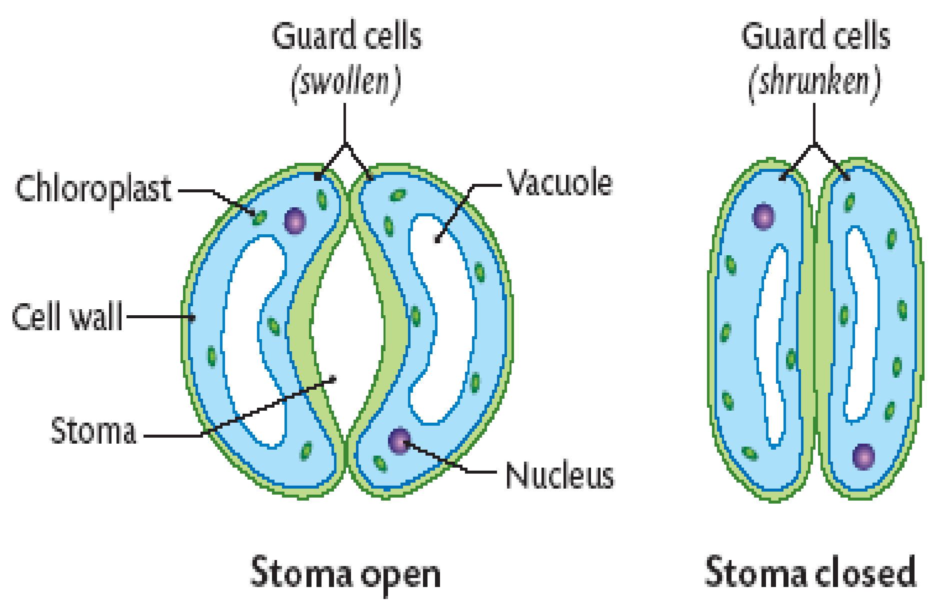


3.3 Physiology of the Stomata

Stomata opening is promoted by:

- **Low intercellular CO_2;** Sensed by guard cells and correspond to the need for more CO_2 to maintain rates of photosynthesis.

- **High light intensity;** Light absorbed by chlorophyll provides ATP by photophosphorylation, increases proton pumping and opens stomata when light is available.



3.3 Physiology of the Stomata

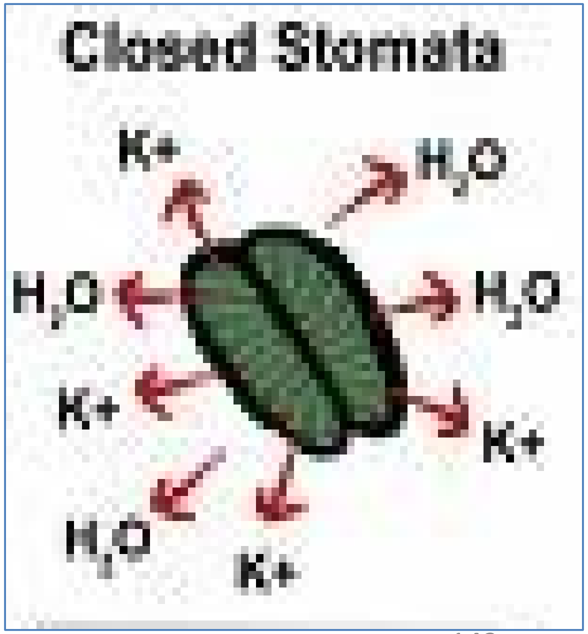
Stomatal closure is triggered by:

1. Low environmental humidity and

2. Increasing leaf temperature;

- **Both are signals that the need to conserve water must override the need to allow CO_2 uptake.**
- **They are feedback response triggered by the water content of leaf epidermal and mesophyll cells.**

- **Note that, at very high temperature stomata may open very wide to allow maximum leaf cooling by evapotranspiration from mesophyll cells.**



3. Abscisic acid (ABA) secretion;

Severe drought stress is detected in epidermal cells which secrete ABA into the apoplast causing rapid and immediate stomatal closure (possibly inhibiting the proton pump).

4.0 Absorption of Mineral Salts

- **Uptake by Roots**
  (movement of ions from soil to roots)
- **Donnan Equilibrium**
- **Accumulation**
- **Factors affecting Salts Absorption**
- **Translocation in the Xylem**

4.0 Absorption of Mineral Salts

- We have discuss how water move into, through and out of plants and how physiological processes (e.g. osmosis) are essential for the movement of water.

- Osmosis could not occur unless movement of water was much faster than that of solutes.

- However solutes do move from cell to cell and from one organelle to the other, as it is essential for life.

- In plants carbon, oxygen and hydrogen are provided by water and atmospheric CO_2 and O_2 but the 13 other essential elements to all plant are absorbed as ions from the soil.

4.0 Absorption of Mineral Salts

4.1 Uptake by Roots

- **In vascular plants inorganic salts (minerals) are mainly absorbed by the roots in the form of ions along with water from dilute solution that surrounds soil particles (*Ions are atoms or groups of atoms which carry either a positive or negative charge*).**

- **How do ions move from roots to the shoots, when the concentration of the cell sap is higher than that of the soil solution, as the process cannot be explained on basis of simple diffusion.**

- **Ions therefore, make their entrance into cells, independently of the rate of absorption of water, from region of lower concentration (soil solution) to region of higher concentration (cell sap).**

4.0 Absorption of Mineral Salts

4.1 Uptake by Roots

- **The component ions of the salts are taken up individually and independently of one another.**
- **They can accumulate to a concentration that far exceeds that of the surrounding medium.**

- **Plants mainly absorbs and retain solutes (against a diffusion or electrical gradient) through the expenditure of energy (metabolic energy).**

- **Active transport (as it is usually called) is the principal method of salt absorption energized by the special energy storing molecules of ATP.**

4.0 Absorption of Mineral Salts

4.1 Uptake by Roots

- To a lesser extent ions can also be absorbed **passively** (non-metabolic energy) along a diffusion gradient without expenditure of energy referred to as **passive transport**.
- This happens when the concentration of the salts in soil solution is higher than that in the cytoplasm e.g. borate, silicate and sometimes calcium.
- This also occur in **saline soils** with high chloride ions.

- **Absorption of ions is selectively higher for some ion over another e.g. essential ions such as K^+ ion are more readily taken up than the similar but non-essential Na^+ ion.**

4.0 Absorption of Mineral Salts

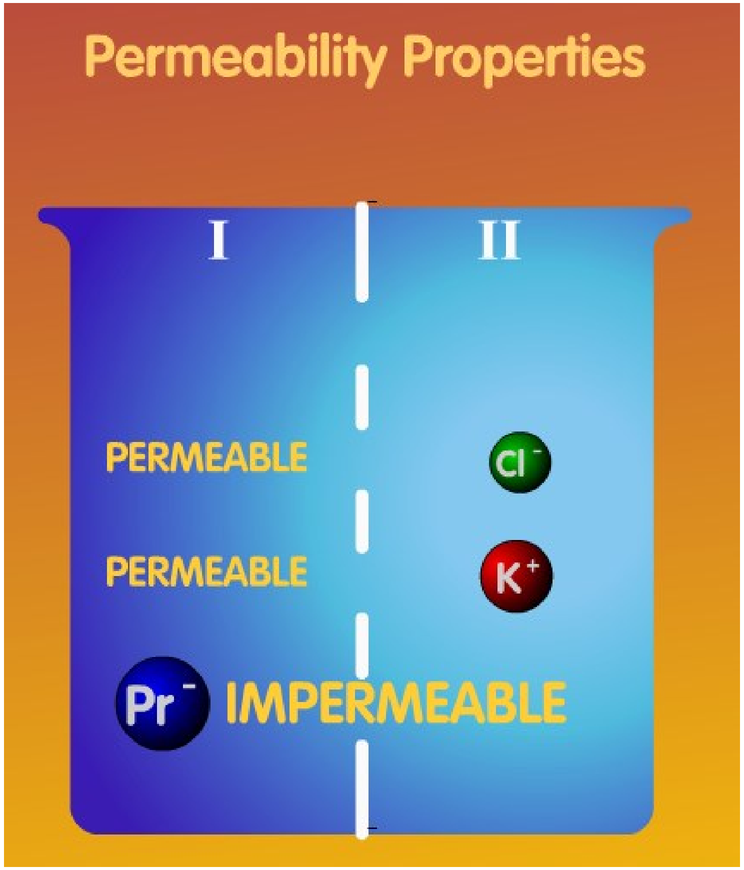
4.2 Donnan Equilibrium

- The mechanism of **active ion uptake** can be demonstrated by the **Donnan Equilibrium**.
- It is the equilibrium set up when **two ionic solutions are separated by a selectively permeable membrane**, maintaining an **unequally distribution of ionic solute**.
- The membrane is such that it allows the passage of certain charged ions of the solutions, according to their size.
- **Ions can be too large to pass through to the other side of the membrane.**
- The concentration of these ions that can pass freely through the membrane are the same on both sides.

4.2 Donnan Equilibrium

- However, as a result of (**the unevenly distribution**) one solution having more of a certain type of ion than the other solution, **an electrical potential gradient between the two solutions develops**.
- Hence the passage of some ions across the membrane is promoted.

4.2 Donnan Equilibrium

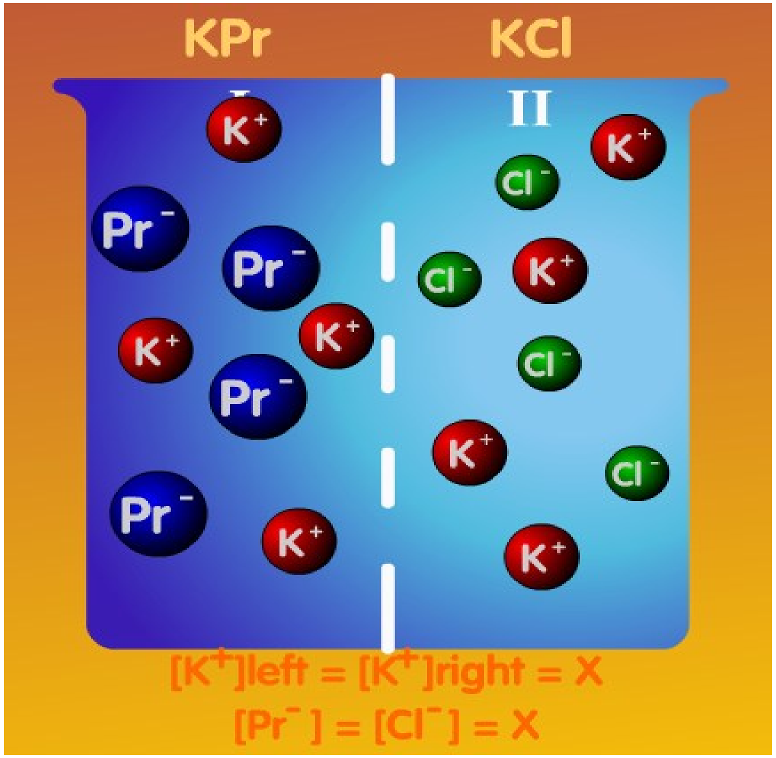


The membrane is such that it allows the passage of certain charged ions of the solutions, according to their size.

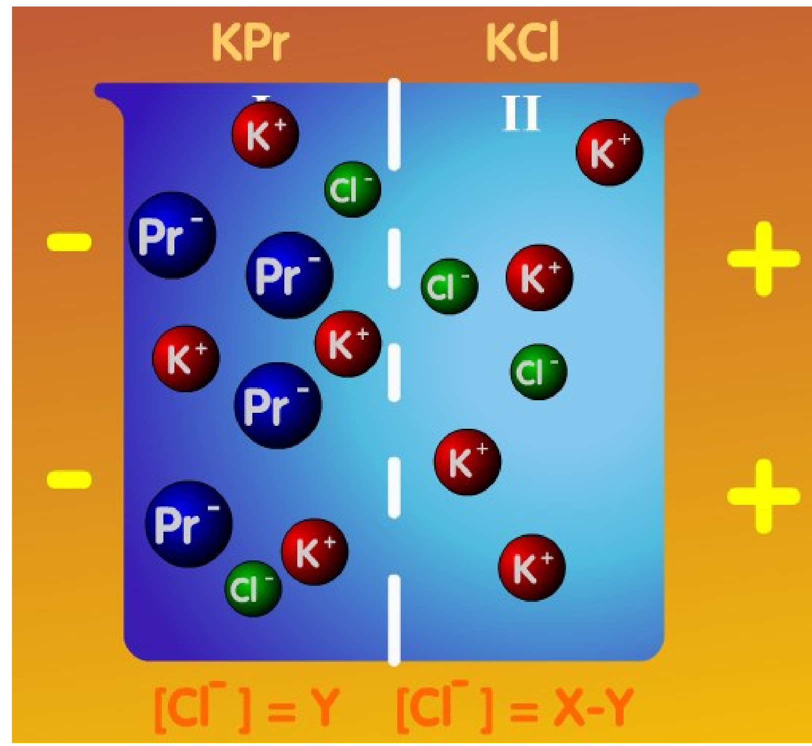
Pr^- = anionic protein

4.0 Absorption of Mineral Salts

4.2 Donnan Equilibrium



Selectively permeable movement of chloride ions (Cl^-)

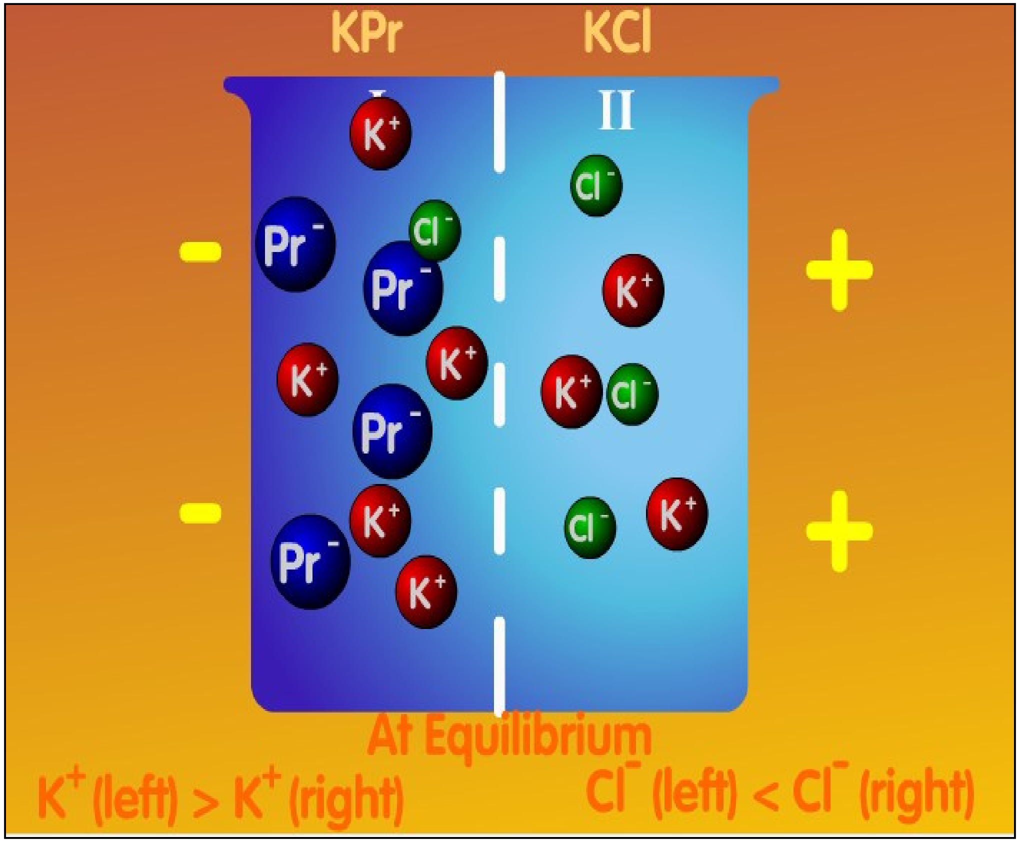


Electrical gradient influx

4.0 Absorption of Mineral Salts

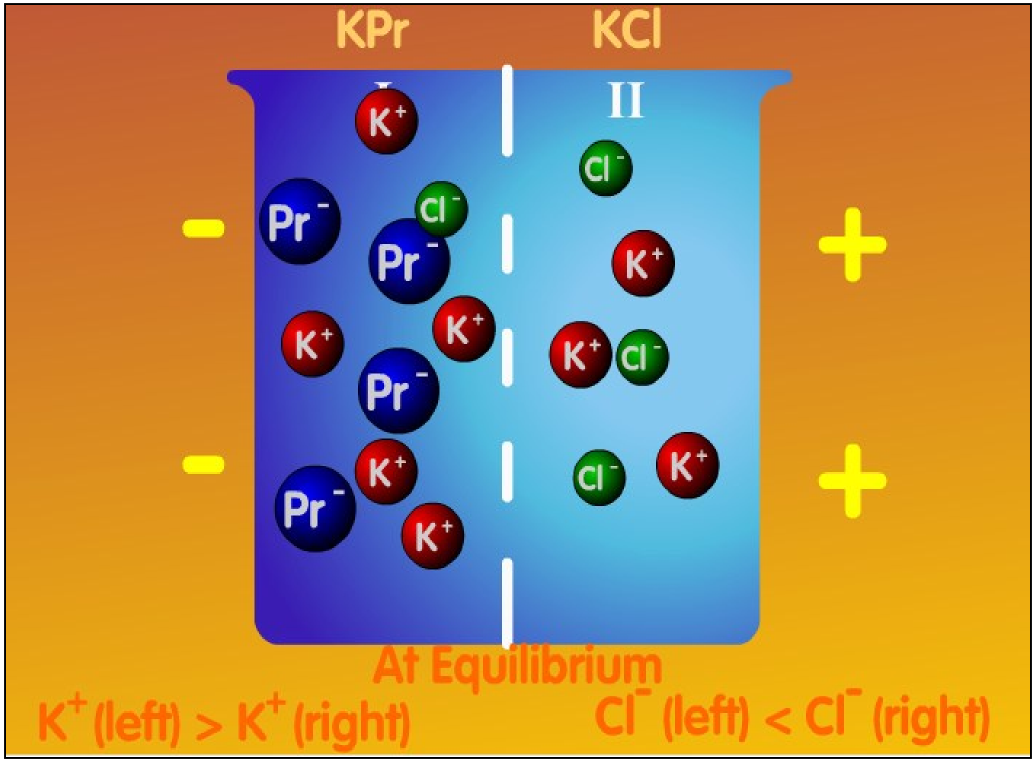
4.2 Donnan Equilibrium

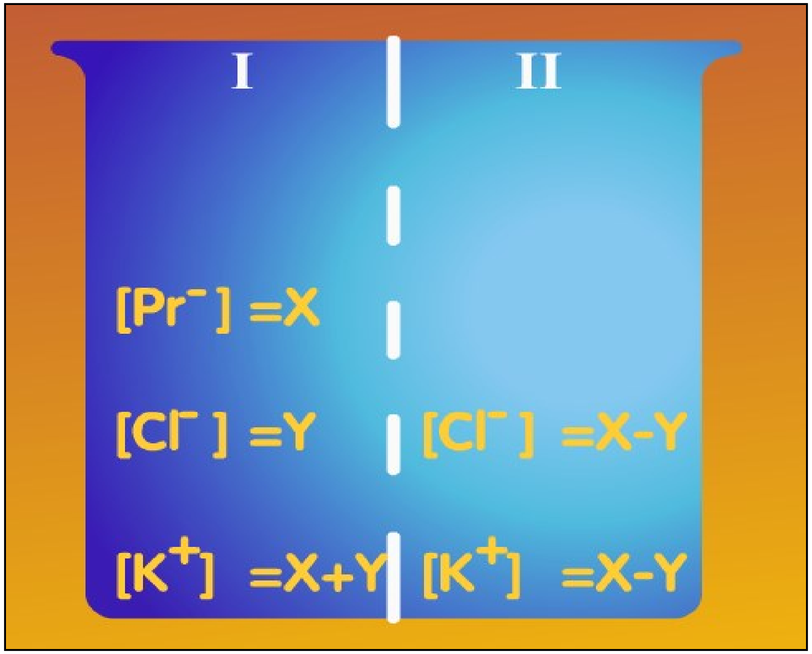
- Permeable ions will migrate from one side to the other according to the electrical gradient that develops.
- The net result at equilibrium is that K^+ and Cl^- will be in equal molar (equimolar) amounts together from one side to the other.



- Each side being electrically neutral within itself, but there is unequal concentration of diffusible ions with K^+ highest on **side 1** and Cl^- highest on **side 2**.

4.2 Donnan Equilibrium





Molar distribution

- **Donnan equilibrium is a process of solutions, that contributes to the formation of an electrical potential across a membrane.**

4.0 Absorption of Mineral Salts

4.3 Accumulation

- Mineral deficiencies can limit the growth of plants.
- Deficiencies can be detected by specific symptoms such as **chlorosis** (loss of chlorophyll resulting from yellow or white leaf tissue), **necrosis** (isolated dead patches), **anthocyanin formation** (development of deep red pigmentation of leaves or stem), **stunted growth** and development of woody tissue in herbaceous plants.

- Nutrient deficiencies in plants can be demonstrated by plants **hydroponically** (growing of plants in liquid nutrient).
- This is a technique which allows plants to be grown in nutrient solutions of selected minerals omitting others in order to determine the resulting effects.

4.0 Absorption of Mineral Salts

4.3 Accumulation

- While mineral deficiencies can limit plant growth over abundance of certain minerals can be toxic and limit growth e.g. heavy metals such as lead, mercury and zinc.

- However, there are certain plants which have the ability to tolerate high levels/quantities of these minerals.

- Such plants that can accumulate minerals in high concentrations are referred to as **hyper-accumulators**.

- Currently scientist are investigating the use of such plants to clean up soil in contaminated and waste sites as an environmentally friendly approach. This process is known as **phytoremediation**.

4.0 Absorption of Mineral Salts

4.4 Factors affecting absorption

The absorption of mineral salts (depends on) is influenced by the following factors:

- Aerobic root respiration
- Amount of light
- Rate of transpiration
- Permeability of cell membrane
- Metabolic activity of the cell
- Influence of temperature
- Hydrogen ion concentration

4.0 Absorption of Mineral Salts

4.5 Transport in the xylem

- From roots to the leaves, ions are transported via the symplast through the plasmodesmata across the root cortex from the epidermis to the xylem vessels.

- From the xylem to the leaves they travel on a long distance process known as **mass flow** (bulk flow).

- This is made possible by the difference in pressure gradient that pull the column of liquid.

5.0 Translocation of solutes

5.1 Transport in the phloem

- The products of photosynthesis (sugars, amino acids, etc) manufactured in the leaves and other green aerial parts (shoots) of plants are transported to other parts of the plant where they are needed via the phloem.

- The movement is multidirectional providing a very flexible transport system.

- The transport of the soluble products of photosynthesis is more commonly referred to as **translocation**.

5.0 Translocation of solutes

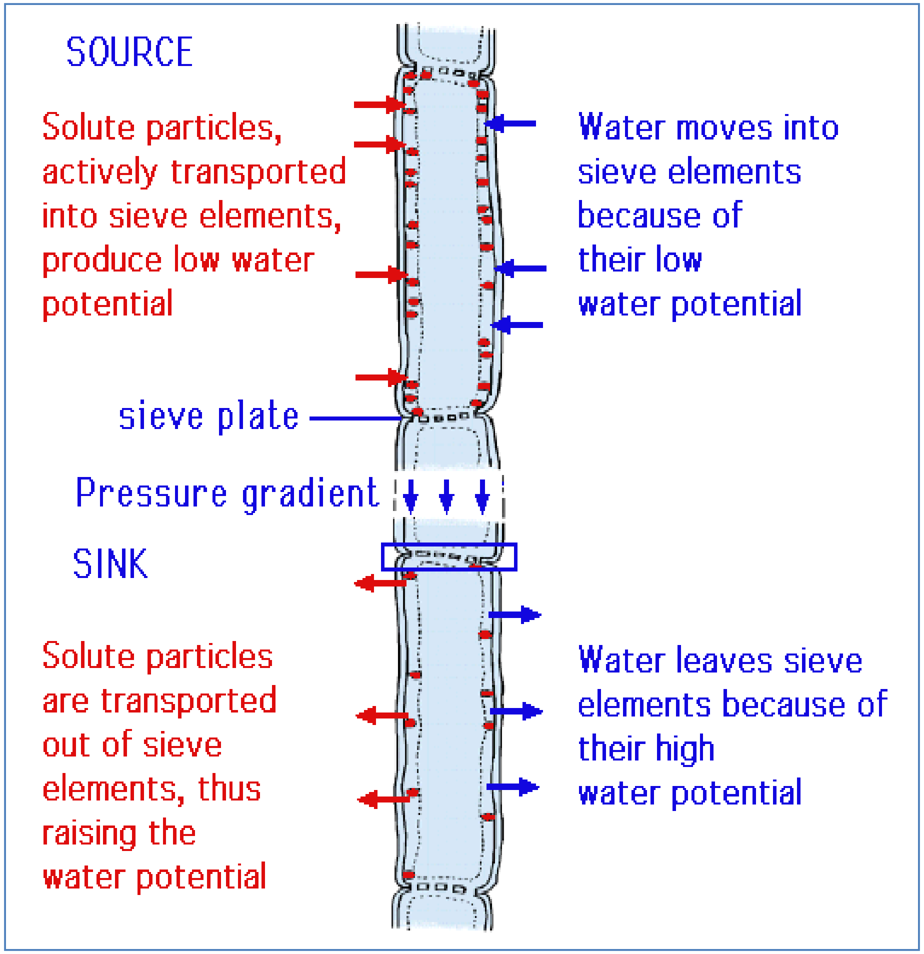
5.2 Mechanism of phloem transportation

- **The products of photosynthesis enters the sieve tubes of the phloem by active transport from the photosynthetic tissues.**

- **In the phloem the driving force of phloem transport is a gradient of hydrostatic pressure within sieve tubes.**

- **The source end of the pathway being of a higher turgor than those of the sink.**

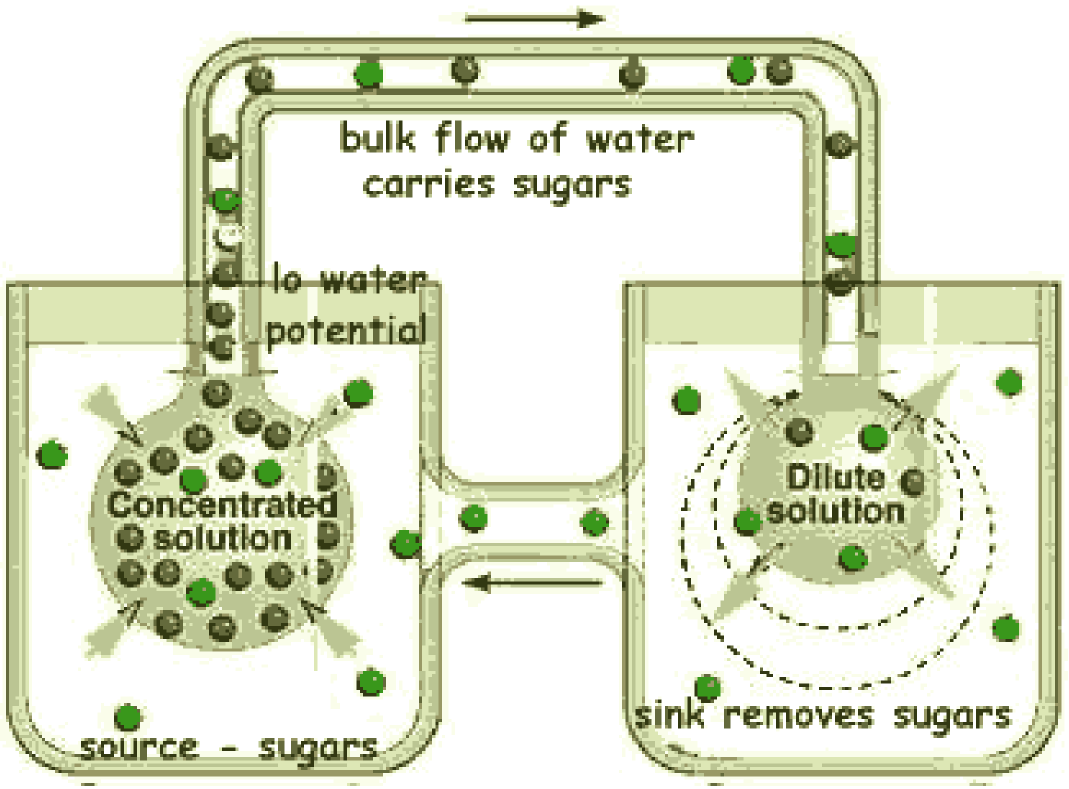
- This phenomenon of passive movement is referred to as **mass flow of solutes**, highest in the leaves where sugar is formed (**the source**) and lowest in the roots (**the sink**).



5.2 Mechanism of phloem transportation

- **Mechanism of mass flow is demonstrated by the following model:**

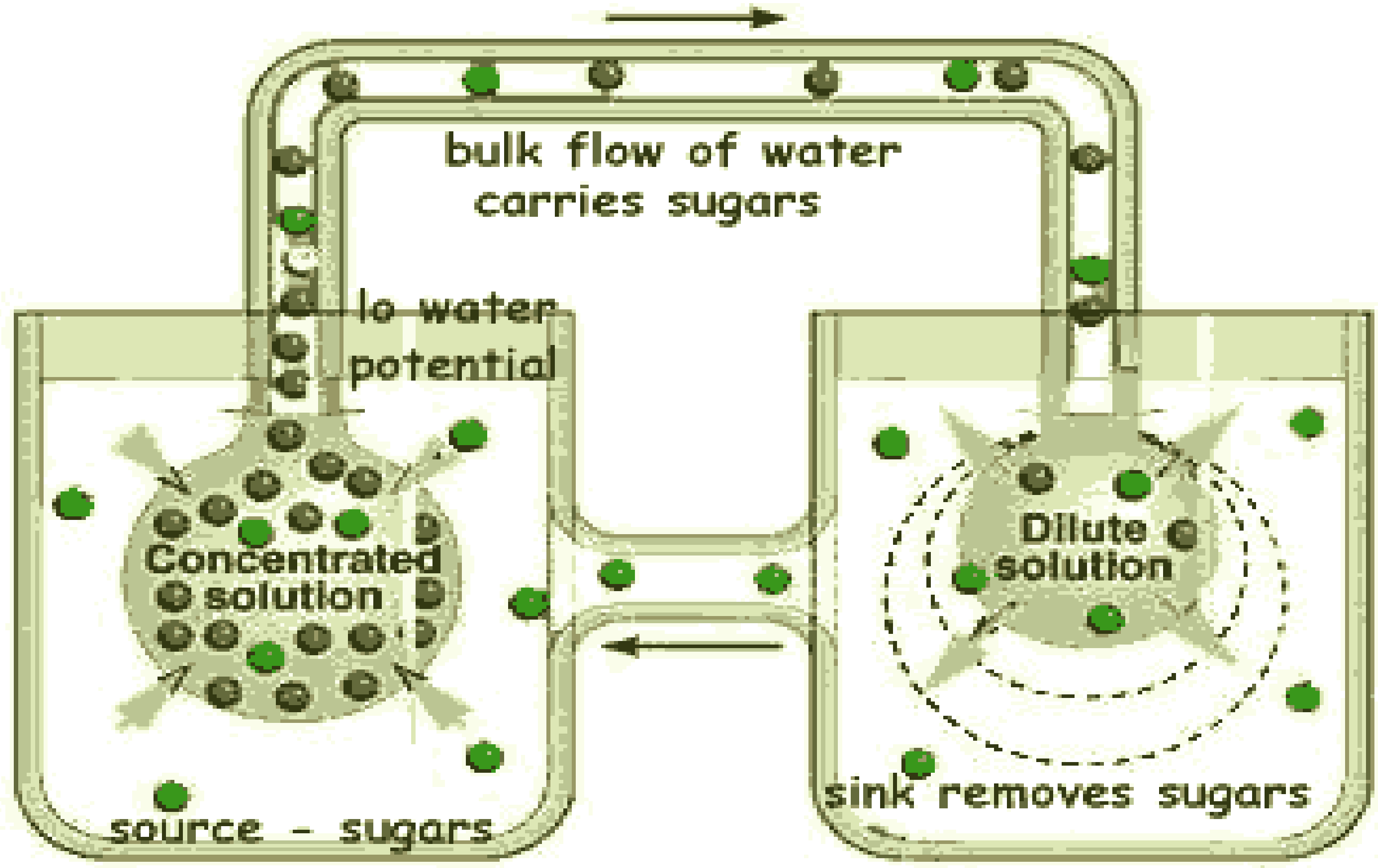
- **Two reservoirs are immersed in water.**
- **Water is drawn into the concentrated solution by osmosis.**
- **Turgor pressure pushes solutes to sink and the solution flows from source to sink.**
- Water is force out of the sink by **hydrostatic pressure**.



- **Removal of sucrose at sink increases water potential causing water to move out of the sink by hydrostatic pressure.**
- **Flow will cease when source and sink are at equilibrium.**

5.2 Mechanism of phloem transportation

- The mechanism of mass flow is demonstrated by the following model:



5.2 Mechanism of phloem transportation

- The mass flow hypothesis is however limited by the lack of explanation for the **bidirectional movement** of solutes within the same sieve tube and calculation of turgor pressure gradient indicate that the pressure would be insufficient to overcome resistance by sieve tubes pores.

- Further explanation for transportation of solutes has been provided by the mechanism of **cytoplasmic streaming**.

- It is suggested that solutes are transported by streaming of solutes along protein filaments of the sieve tubes.

5.2 Mechanism of phloem transportation

- The energy of the process coming from the sieve tube and companion cells.
- It is envisaged that some strands convey solutes downwards, whilst others convey them upwards, thus accounting for the bidirectional flow of solutes.

- It is now generally accepted that solutes moves in and out of sieve tubes at source and sink by active transport, and movement along sieve tubes is by mass flow aided by cytoplasmic streaming.

6.0 The Role of Auxins and Water in Cell Enlargement

Sub topics

6.1 Plant hormones

6.2 Principles of hormones - function

6.3 Auxin role in cell enlargement

6.4 Roles of plant hormones

6.0 The Role of Auxins and Water in Cell Enlargement

6.1 Plant hormones

- A large number of compounds are said to promote or induce growth in plant organs.
- The way in which they work is uncertain but it maybe connected with water uptake.

- **Hormones are chemical messengers that influence the growth and development of plants including flowering and fruiting.**
- They are produced in one part of the plant and have a physiological effect on a target tissue that may be distant from the site of production.

6.0 The Role of Auxins and Water in Cell Enlargement

6.1 Plant hormones

- Unlike animals, plants have no specialized organ(s) designed solely for hormone synthesis and secretion. Leaves, stem tips, root tips, flowers, seeds, and fruits all produce hormones.
- Most plant hormones are functional at very low concentrations.

- The major types of plant hormones are **auxins**, **gibberellins**, **cytokinins**, **abscisic acid** and **ethylene**.
- All are in some way involved in regulating plant growth and development.
- Some promote growth by stimulating cell enlargement or division while others inhibit growth by inducing dormancy or promoting senescence.
- **Cell enlargement is promoted by auxins and gibberellins.**

6.0 The Role of Auxins and Water in Cell Enlargement

6.2 Principles of hormones function

- Often two or more hormones work **synergistically**.

- Experiment using tobacco tissue culture; have shown that auxins and cytokinins work together in the differentiation of plant organs.

- **It was observed that when a tissue culture medium contains low concentrations of auxin and optimal cytokinin levels, then formation of shoots is favoured.**

- **In contrast, when the culture medium is supplied with optimal concentrations of auxin combined with low concentrations of cytokinins, root formation is favoured.**

6.2 Principles of hormones function

- Hormones sometimes work **antagonistically**.
- **Apical dominance** is a process in which lateral buds of stems remain dormant as long as the stem apex remains intact.
- It has been shown that auxin produced in the stem apex is responsible for maintaining lateral bud dormancy by causing cells in the lateral buds to produce another hormone, ethylene, which is a growth inhibitor.

6.0 The Role of Auxins in Cell Enlargement

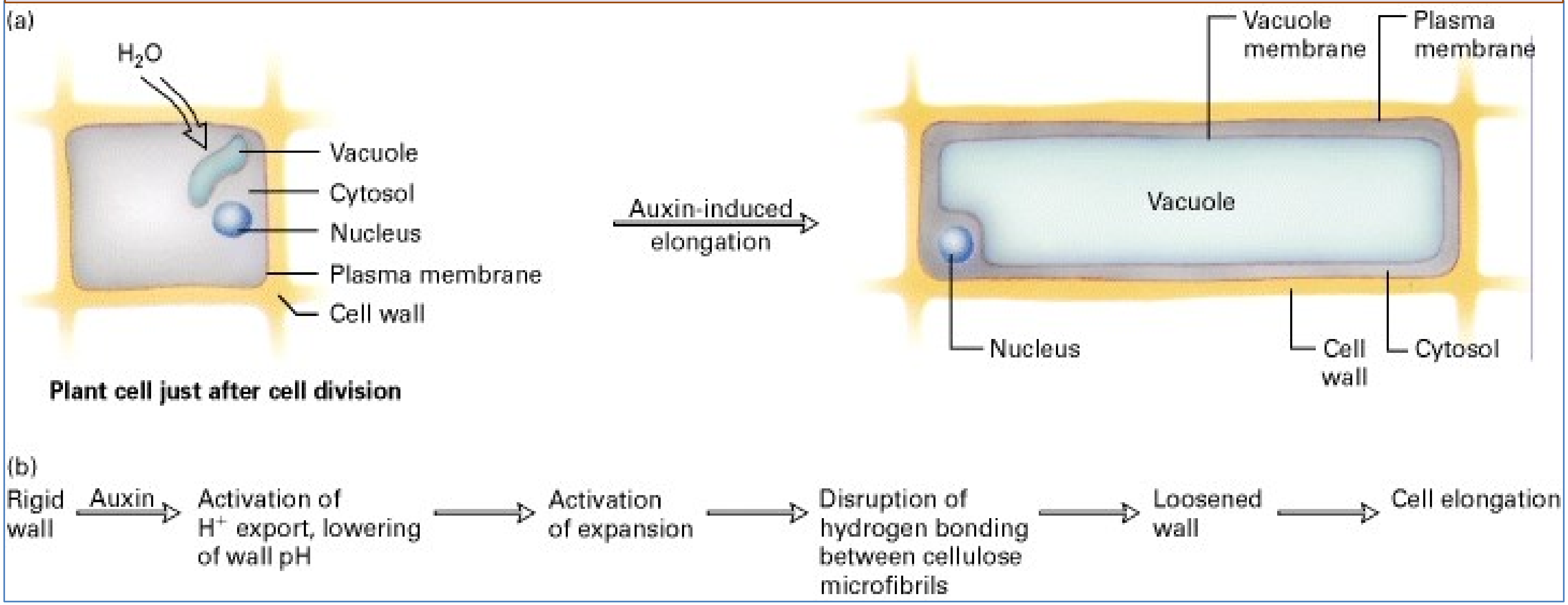
6.3 Auxin role in cell enlargement

- Auxins were the first class of plant hormones to be identified.
- **The most widely studied naturally occurring auxin is indol-3-acetic acid (IAA).**
- Naturally occurring auxins promote cell enlargement, they are important in tropisms, prevent abscission, promote fruit development, and are involved in apical dominance.
- IAA stimulates special pumps in the cell membrane of target cells to release H ions into the cell wall, resulting in a pH drop to approximately 5.0 in the cell wall.
- Enzymes that are pH-dependent then break down important structural bonds between cellulose microfibrils causing an increase in cell wall plasticity.
- As the cell wall becomes more plastic, water is able to flow in and the cell enlarges.

6.0 The Role of Auxins and Water in Cell Enlargement

6.3 Auxin role in elongation of plant cells

Proposed mechanism of cell-wall loosening in plant cells



Change in structure of a plant cell during elongation.

a) **Uptake of water causes an internal pressure (turgor); in the presence of auxin,**

b) **the cell-wall is loosened, and the turgor pressure against the loosened wall leads to elongation.**

6.0 The Role of Auxins and Water in Cell Enlargement

6.4 Plant hormones – summary of roles

- **Auxins**: Involved in differentiation of vascular tissue, control cellular elongation, prevention of abscission, involved in apical dominance and various tropisms, stimulate the release of ethylene, enhance fruit development.
- **Cytokinins**: Affect cell division, delay senescence, activate dormant buds.
- **Gibberellins**: Initiate mobilization of storage materials in seeds during germination, cause elongation of stems, stimulate bolting (Premature seeds production) in biennials, stimulate pollen tube growth.
- **Abscisic Acid**: Maintains dormancy in seeds and buds, stimulates the closing of stomata.
- **Ethylene**: Causes ripening of climacteric fruits, promotes abscission, causes formation of aerenchyma tissue.

6.4 Plant hormones – summary of roles

- **Jasmonates:** Involved in response to environmental stresses, control germination of seeds.

- **Brassinolides:** Promote of elongation, stimulate flowering, promote cell division, can affect tropic curvature.

- **Salicylic Acid:** Activates genes involved with plant's defence mechanisms.

Plant cell has a very complex physio-chemical nature, continually changing in response to its environment