NCERT Exemplar Solutions of Class 11 Biology – Chapter 11: Transport in plants

VERY SHORT ANSWER TYPE QUESTIONS

1. Smaller, lipid-soluble molecules diffuse faster through the cell membrane, but the movement of hydrophilic substances are facilitated by certain transporters which are chemically ____________.

Solution: Answer: proteins

Enhanced Explanation: Transport proteins (channel proteins, carrier proteins) are integral membrane proteins that facilitate the movement of hydrophilic substances across cell membranes. These proteins provide specific pathways for substances that cannot easily cross the lipid bilayer due to their polar or charged nature.

2. In passive transport across a membrane, when two different molecules move in the opposite direction and independent of each other, it is called ___________.

Solution: Answer: Antiport

Enhanced Explanation: Antiport is a type of secondary active transport where two different molecules or ions move in opposite directions across a membrane. Examples include Na^+-K^+ ATPase pump and Na^+-Ca^{2+} exchanger.

3. Osmosis is a special kind of diffusion, in which water diffuses across the cell membrane. The rate and direction of osmosis depends upon both ______________.

Solution: Answer: Pressure and concentration gradient

Enhanced Explanation: Osmosis depends on:

- Concentration gradient (difference in solute concentration)
- Pressure gradient (difference in hydrostatic pressure) These factors determine the water potential difference that drives osmotic movement.

4. A flowering plant is planted in an earthen pot and irrigated. Urea is added to make the plant grow faster, but after some time the plant dies. This may be due to _______________ .

Solution: Answer: Exosmosis

Enhanced Explanation: Excess urea creates a hypertonic soil solution, causing water to move out of plant roots through exosmosis. This leads to dehydration and eventually plant death, demonstrating the importance of proper fertilizer concentration.

5. Absorption of water from the soil by dry seeds increases the _____________, thus helping seedlings to come out of the soil

Solution: Answer: Pressure

Enhanced Explanation: Imbibition by dry seeds increases turgor pressure within the seed, causing it to swell and exert mechanical pressure that helps rupture the seed coat and push the emerging seedling through the soil surface.

6. Water moves up against gravity and even for a tree of 20m height, the tip receives water within two hours. The most important physiological phenomenon which is responsible for the upward movement of water is _______________________.

Solution: Answer: Transpiration pull

Enhanced Explanation: Transpiration pull, generated by water evaporation from leaves, creates a negative pressure that pulls water up through the xylem. Combined with cohesion-adhesion properties of water, this mechanism can transport water to great heights efficiently.

7. The plant cell cytoplasm is surrounded by both cell wall and cell membrane. The specificity of transport of substances are mostly across the cell membrane, because ___________________.

Solution: Answer: The cell wall is freely permeable to water and substances in solutions but the membrane is selectively permeable

Enhanced Explanation: The cell wall provides structural support but is freely permeable to most substances. The cell membrane, being selectively permeable, controls what enters and exits the cell, maintaining cellular homeostasis and enabling specific transport mechanisms.

8. The C4 plants are twice as efficient as C3 plants in terms of fixing CO2 but lose only __________ as much water as C3 plants for the same amount of CO2 fixed.

Solution: Answer: Half

Enhanced Explanation: C4 plants have evolved efficient CO2 concentrating mechanisms that allow them to maintain photosynthesis with partially closed stomata, reducing water loss while maintaining high CO2 fixation rates.

9. In a plant, translocation in the xylem is unidirectional while in phloem it is bidirectional. Explain.

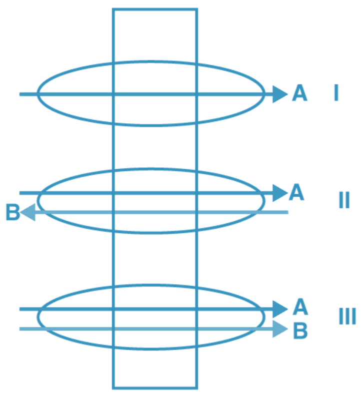
Solution: Enhanced Explanation: Xylem translocation is unidirectional (upward) because:

- Water and minerals move from roots to shoots
- Driven by transpiration pull and root pressure
- No reversal of direction needed

Phloem translocation is bidirectional because:

- Food moves from source to sink
- Source and sink can change seasonally
- During spring, stored food in roots moves to growing shoots
- During growing season, leaves transport food to roots and fruits
- The direction depends on metabolic demands and seasonal changes

10. Identify the process occurring in I, II and III



[Figure shows three types of membrane transport mechanisms]

Solution: I) **Uniport** - Single substance moves in one direction II) **Antiport** - Two substances move in opposite directions

III) **Symport** - Two substances move in the same direction

Enhanced Explanation: These represent different types of membrane transport:

- **Uniport**: Simple transport of one molecule type
- **Antiport**: Counter-transport maintaining ionic balance
- **Symport**: Co-transport where one molecule's movement drives another's

11. Given below is a table. Fill in the gaps

Property	Simple diffusion	Facilitated transport	Active Transport
i. Highly selective	A	Yes	F
ii Uphill transport	B	D	Yes
iii Requires ATP	C	E	G

Solution: A, B, C, D, E = **No** F and G = **Yes**

Enhanced Explanation:

- **Simple diffusion**: Non-selective, no uphill transport, no ATP required
- **Facilitated transport**: Selective, no uphill transport, no ATP required
- **Active transport**: Highly selective, enables uphill transport, requires ATP

12. Define water potential and solute potential.

Solution: Water potential (Ψw) is the sum of solute potential (Ψs) and pressure potential (Ψp): **$\Psi w = \Psi s + \Psi p$**

Solute potential (Ψs) is the potential of a solution that allows water to enter by diffusion or osmosis due to the presence of solute particles. It represents the effect of dissolved solutes on water potential.

Enhanced Explanation:

- Water potential determines the direction of water movement
- Pure water has $\Psi w = 0$ at standard conditions
- Solute potential is always negative (lowers water potential)
- Pressure potential can be positive (turgor) or negative (tension)

13. Why is solute potential always negative? Explain $\psi w = \psi s + \psi p$

Solution: Enhanced Explanation: Solute potential is always negative because:

- Pure water has the highest water potential (0)
- Adding solutes decreases water's tendency to move freely
- Solute particles bind water molecules, reducing water potential
- The more concentrated the solution, the more negative the solute potential

The equation $\psi w = \psi s + \psi p$ shows:

- ψw (water potential) = net driving force for water movement
- ψs (solute potential) = effect of dissolved solutes (always ≤ 0)
- ψp (pressure potential) = physical pressure effects (can be +/-)

14. Tradescantia leaf epidermal peel was taken and
a. Placed in the salt solution for five minutes. b. After that, it was placed in distilled water. When seen under the microscope what would be observed in a and b?
Solution: a. **Plasmolysis observed** - The cells shrink as the salt solution is hypertonic, causing water to move out of cells through exosmosis. The plasma membrane pulls away from the cell wall.
b. **Deplasmolysis observed** - When placed in distilled water (hypotonic), the cells regain turgidity as water moves in through endosmosis. The plasma membrane returns to its normal position against the cell wall.
Enhanced Explanation: This experiment demonstrates osmotic behavior in living cells and the reversible nature of plasmolysis under appropriate conditions.
15. Differentiate between Apoplast and Symplast pathways of water movement. Which of these would need active transport?
Solution:

Aspect	Apoplast Pathway	Symplast Pathway
Route	Through cell walls and intercellular spaces	Through cytoplasm and plasmodesmata
Living/Non-living	Non-living components	Living components
Mechanism	Passive diffusion	Osmosis
Resistance	Lower resistance	Higher resistance
Control	Less regulated	More regulated

Active transport requirement: Symplast pathway needs active transport, especially when crossing membranes against concentration gradients.
Enhanced Explanation: The symplast pathway requires energy for:
- Active uptake across plasma membranes
- Maintaining concentration gradients
- Selective transport processes

16. How does water moves within the root?
Solution: Enhanced Explanation: Water movement in roots occurs through three pathways:
1. **Apoplast pathway** (60-70%):
   - Water moves through cell walls and intercellular spaces
   - Passive movement driven by transpiration pull
   - Blocked at endodermis by Casparian strips
2. **Symplast pathway** (20-30%):
   - Water moves through cytoplasm via plasmodesmata
   - Requires crossing plasma membranes
   - More controlled pathway
3. **Transcellular pathway**:

- Water crosses individual cell membranes
- Involves membrane transporters
- Slower but selective

Water entry is driven by water potential gradients from soil → root hair → cortex → endodermis → xylem.

17. Give the location of the Casparian strip and explain its role in the water movement.

Solution: Location: Casparian strips are located in the endodermal cell walls (radial and transverse walls) of plant roots.

Role in water movement:

- **Blocks apoplast pathway**: Prevents water and solutes from moving freely through cell walls
- **Forces symplast route**: Water must pass through endodermal cell membranes
- **Selective barrier**: Allows selective uptake of minerals and water
- **Creates positive pressure**: Helps establish and maintain positive hydrostatic pressure in the xylem
- **Prevents backflow**: Stops water and solutes from leaking back to the cortex

Enhanced Explanation: This structure ensures that all water and solutes entering the vascular system are filtered through living endodermal cells, providing quality control for what reaches the plant's transport system.

18. Differentiate between guttation and transpiration.

Solution:

Aspect	Transpiration	Guttation
Process	Loss of water as vapor	Loss of water as liquid droplets
Location	Through stomata on leaf surfaces	Through hydathodes at leaf margins
Time	Mainly during day	Mainly at night/early morning
Mechanism	Evaporation	Root pressure
Conditions	Low humidity, high temperature	High humidity, high soil moisture
Water type	Pure water vapor	Water with dissolved minerals

Enhanced Explanation: Both processes help maintain water balance but operate under different conditions and serve different physiological purposes.

19. Transpiration is a necessary evil in plants. Explain.

Solution: "Necessary evil" concept explained:

Necessary because:

- **Cooling effect**: Prevents overheating of leaves
- **Mineral transport**: Drives upward movement of minerals
- **Water transport**: Creates transpiration pull for water ascent
- **Maintains turgor**: Helps maintain plant structure
- **Gas exchange**: Stomatal opening allows CO_2 entry for photosynthesis

Evil because:

- **Water loss**: Can lead to wilting and plant death
- **Energy cost**: Plants must invest in water absorption mechanisms
- **Vulnerability**: Makes plants susceptible to drought stress
- **Limits distribution**: Restricts plant growth in arid environments

Enhanced Explanation: Transpiration is essential for plant function but comes with the cost of water loss, requiring plants to balance gas exchange needs with water conservation.

20. Describe briefly the three physical properties of water which helps in the ascent of water in the xylem.

Solution:

1. **Adhesion**: Attraction between water molecules and xylem vessel walls
   - Allows water to "stick" to vessel surfaces
   - Prevents water column from falling due to gravity
   - Helps maintain continuous water column
2. **Cohesion**: Force holding water molecules together through hydrogen bonding
   - Creates strong intermolecular attraction
   - Maintains water column integrity during transport
   - Provides tensile strength to resist breaking under tension
3. **Surface tension**: Property allowing water surface to resist external force
   - Results from cohesive forces at air-water interfaces
   - Supports capillary action in narrow xylem vessels
   - Helps in initial water uptake in fine root hairs

Enhanced Explanation: These properties work together to enable water transport from roots to leaves in tall trees, creating a continuous hydraulic system that can operate against gravity.

21. A gardener forgot to water a potted plant for a day during summer, what will happen to the plant? Do you think it is reversible? If yes, how?

Solution: What happens:

- **Wilting occurs**: Plant loses turgidity due to excessive water loss
- **Stomatal closure**: Plant closes stomata to reduce further water loss
- **Metabolic slowdown**: Photosynthesis and other processes reduce
- **Drooping leaves**: Loss of turgor pressure causes structural collapse

Reversibility: Yes, it is reversible if:

- Water stress is not prolonged
- Plant tissues haven't suffered permanent damage
- Root system remains functional

Recovery mechanism:

1. **Immediate watering**: Restores soil moisture
2. **Water absorption**: Roots begin rapid water uptake
3. **Turgor restoration**: Cells regain internal pressure

4. **Stomatal reopening**: Normal gas exchange resumes
5. **Structural recovery**: Leaves and stems regain rigid posture

Enhanced Explanation: Temporary wilting is a protective mechanism, but prolonged stress can cause permanent damage to cellular structures.

22. Identify a type of molecular movement which is highly selective and requires special membrane proteins, but does not require energy

Solution: Answer: Facilitated diffusion (passive transport)

Enhanced Explanation: Facilitated diffusion characteristics:

- **Highly selective**: Uses specific transport proteins (channels, carriers)
- **Protein-dependent**: Requires integral membrane proteins
- **No energy required**: Moves along concentration gradient
- **Examples**:
    - Glucose transport via GLUT proteins
    - Ion movement through specific channels
    - Water movement through aquaporins

This process combines the selectivity of active transport with the energy efficiency of simple diffusion.

23. Correct the statements

a. Cells shrink in hypotonic solutions and swell in hypertonic solutions. b. Imbibition is a special type of diffusion when water is absorbed by living cells. c. Most of the water flow in the roots occurs via the symplast.

Solution: Corrected statements:

a. **Cells shrink in hypertonic solutions and swell in hypotonic solutions.**

- Hypertonic = higher solute concentration outside → water moves out → cell shrinks
- Hypotonic = lower solute concentration outside → water moves in → cell swells

b. **Imbibition is a special type of diffusion when water is absorbed by dead or living cells.**

- Imbibition occurs in both living and non-living materials
- Examples: dry seeds (living), paper (non-living), wood (dead tissue)

c. **Most of the water flow in roots occurs via the apoplast pathway.**

- Apoplast pathway carries majority (60-70%) of water transport
- Lower resistance pathway through cell walls and spaces

SHORT ANSWER TYPE QUESTIONS

1. Minerals absorbed by the roots travel up the xylem. How do they reach the parts where they are needed most? Do all the parts of the plant get the same amount of the minerals?

Solution: Mineral distribution mechanism:

1. **Xylem transport**: Minerals move upward with transpiration stream
2. **Lateral transport**: Movement from xylem to surrounding tissues
3. **Phloem redistribution**: Some minerals can move through phloem
4. **Remobilization**: Mobile minerals move from old to young tissues

Unequal distribution:

- **No, all parts don't receive equal minerals**
- **Priority system**: Growing points (meristems) receive priority
- **Metabolic demand**: Active tissues get more minerals
- **Element mobility**: Mobile elements (N, P, K, Mg) redistribute easily
- **Immobile elements**: Ca, Fe, B remain where first deposited

Enhanced Explanation: Plants have evolved sophisticated mechanisms to ensure minerals reach where they're needed most, with young growing tissues typically receiving priority over older, mature parts.

2. If one wants to find minerals and in the form, they are mobilised in the plant, how will an analysis of the exudate help?

Solution: Exudate analysis benefits:

What are exudates:

- Plant sap that oozes from cut surfaces
- Contains both xylem and phloem sap
- Represents transported minerals in their mobile forms

Information provided:

1. **Chemical forms**: How minerals exist during transport (organic vs inorganic)
2. **Concentration levels**: Relative abundance of different minerals
3. **Seasonal variation**: Changes in mineral transport patterns
4. **Organic complexes**: Minerals bound to organic molecules
5. **pH and ionic strength**: Transport medium conditions

Research applications:

- **Nutritional studies**: Understanding plant mineral requirements
- **Transport mechanisms**: How plants mobilize stored minerals
- **Deficiency diagnosis**: Identifying limiting nutrients
- **Breeding programs**: Selecting for improved mineral transport

Enhanced Explanation: Exudate analysis provides a direct window into the plant's internal transport system, revealing both the identity and chemical form of mobile minerals.

3. From your knowledge of physiology can you think of some method of increasing the life of cut plants in a vase?

Solution: Methods to extend cut flower life:

1. **Use cytokinins**: Plant growth hormones that delay senescence (aging)
   - Maintains cellular metabolism
   - Prevents premature aging of tissues
2. **Proper water immersion**: Keep cut stem submerged
   - Prevents air bubbles (embolism) in xylem
   - Maintains continuous water column
3. **Clean, sharp cuts**: Make fresh cuts under water
   - Maximizes water uptake surface
   - Prevents xylem blockage

4. **Floral preservatives**: Commercial solutions containing:
    - Sugar (energy source)
    - Antibiotics (prevent bacterial growth)
    - Acidifiers (improve water uptake)
5. **Environmental control**:
    - Cool temperatures (reduce metabolic rate)
    - High humidity (reduce transpiration)
    - Avoid direct sunlight
6. **Regular maintenance**:
    - Change water frequently
    - Trim stems periodically
    - Remove dead/dying parts

Enhanced Explanation: The key is maintaining water transport while reducing water loss and metabolic demands on the cut tissues.

4. Do different species of plants growing in the same area show the same rate of transpiration at a particular time? Justify your answer.

Solution: No, different species show different transpiration rates.

Factors causing variation:

1. **Morphological differences**:
    - **Leaf area**: Larger leaves = more transpiring surface
    - **Cuticle thickness**: Waxy cuticles reduce water loss
    - **Stomatal density**: More stomata = higher transpiration
    - **Leaf orientation**: Vertical leaves reduce exposure
2. **Anatomical adaptations**:
    - **Stomatal size and distribution**: Affects gas exchange capacity
    - **Internal air spaces**: Influence water vapor movement
    - **Vascular arrangement**: Affects water transport efficiency
3. **Physiological mechanisms**:
    - **Stomatal control**: Different sensitivity to environmental factors
    - **Water use efficiency**: C3 vs C4 vs CAM plants differ significantly
    - **Osmotic adjustment**: Ability to maintain turgor under stress
4. **Evolutionary adaptations**:
    - **Desert plants**: Reduced leaf area, thick cuticles, CAM metabolism
    - **Aquatic plants**: Thin cuticles, large stomata
    - **Forest plants**: Adapted for humid conditions

Enhanced Explanation: Each species has evolved specific adaptations for their ecological niche, resulting in characteristic transpiration rates that optimize survival in their environment.

5. Water is indispensable for life. What properties of water make it useful for all biological processes on the earth?

a) Water is a polar solvent due to which it is regarded as the 'universal solvent'. b) Water has a high specific heat capacity. c) Water has low viscosity and high surface tension. d) The density of water decreases below 4°C. e) Capillarity of water

Solution:

a) **Universal solvent property**:

- Polar nature allows dissolution of ionic and polar compounds
- Essential substances in living organisms are water-soluble
- Facilitates transport of nutrients and waste products
- Enables biochemical reactions in aqueous medium

b) **High specific heat capacity**:

- Large amount of energy required to change temperature
- Provides thermal stability to organisms
- Prevents rapid temperature fluctuations
- Maintains enzyme function within optimal temperature ranges

c) **Low viscosity and high surface tension**:

- **Low viscosity**: Easy flow through narrow vessels and capillaries
- **High surface tension**: Cohesion of water molecules enables:
    - Formation of water columns in xylem
    - Capillary action in plants
    - Water droplet formation

d) **Density changes below 4°C**:

- Water expands when freezing, making ice less dense
- Ice floats on water surface
- Insulates underlying water, protecting aquatic life
- Prevents complete freezing of water bodies

e) **Capillarity**:

- Water rises in narrow tubes against gravity
- Essential for water transport in plants
- Helps in soil water movement to roots
- Facilitates water distribution in plant tissues

Enhanced Explanation: These unique properties of water make it not just suitable but essential for life, creating the physical and chemical environment necessary for biological processes.

6. How are the intracellular levels of ions maintained higher than extracellular levels in animal cells?

Solution: Ion concentration maintenance mechanisms:

1. **ATP-powered pumps**:
    - **Na^+-K^+ ATPase pump**: Most important example
    - Exchanges 3 Na^+ out for 2 K^+ in per ATP molecule
    - Creates and maintains electrochemical gradients

   - Consumes ~30% of cellular ATP
2. **Secondary active transport**:
   - Uses Na^+ gradient to drive other ion movements
   - **Symporters**: Co-transport (Na^+-glucose, Na^+-amino acids)
   - **Antiporters**: Counter-transport (Na^+-Ca^{2+}, Na^+-H^+)
3. **Selective membrane permeability**:
   - Lipid bilayer restricts passive ion movement
   - Specific channels control ion flow
   - Gated channels respond to stimuli
4. **Intracellular ion binding**:
   - Proteins buffer free ion concentrations
   - Organelles sequester specific ions
   - Calcium-binding proteins regulate Ca^{2+} levels

Result: Typical intracellular vs extracellular concentrations:

- K^+: 140 mM inside vs 5 mM outside
- Na^+: 10 mM inside vs 145 mM outside
- Ca^{2+}: 0.1 µM inside vs 1.5 mM outside

Enhanced Explanation: This active maintenance of ion gradients is essential for cellular processes including nerve conduction, muscle contraction, and osmotic regulation.

7. Cut pieces of beetroot do not leave colour in cold water but do so in hot water. Explain.

Solution: Temperature effect on membrane integrity:

Cold water (no color release):

- **Membrane remains intact**: Phospholipid bilayer maintains structure
- **Selective permeability preserved**: Membrane controls what passes through
- **Cellular compartmentalization maintained**: Pigments stay in vacuoles
- **Normal membrane proteins function**: Transport is regulated

Hot water (color release):

- **Membrane denaturation**: High temperature disrupts lipid organization
- **Protein denaturation**: Membrane proteins lose function
- **Loss of selective permeability**: Membrane becomes leaky
- **Pigment release**: Betalain pigments escape from vacuoles
- **Cell death**: Cellular organization breaks down

Enhanced Explanation: The beetroot color experiment demonstrates how temperature affects membrane integrity. The red/purple betalain pigments are normally contained within vacuoles, but membrane damage at high temperatures allows these pigments to leak out, coloring the surrounding water.

This principle is used in:

- **Cell viability tests**: Membrane integrity as life indicator
- **Food processing**: Understanding thermal effects on plant tissues
- **Preservation methods**: Heat treatment affects cellular structure

8. In a girdled plant, when water is supplied to the leaves above the girdle, leaves may remain green for some time then wilt and ultimately die. What does it indicate?

Solution: Girdling experiment analysis:

What girdling does:

- **Removes bark and phloem**: Cuts off sugar transport from leaves
- **Xylem remains intact**: Water transport continues initially
- **Isolates upper and lower plant parts**: Creates physiological separation

Why leaves remain green initially:

- **Photosynthesis continues**: Leaves can make their own sugar from CO_2 and water
- **Local energy production**: Leaf cells meet immediate energy needs
- **Chlorophyll synthesis maintained**: Short-term metabolic processes function

Why leaves eventually die:

1. **Sugar accumulation**: Cannot export photosynthetic products downward
2. **Osmotic stress**: High sugar concentration affects water balance
3. **Metabolic disruption**: Feedback inhibition of photosynthesis
4. **Nutrient deficiency**: Cannot receive minerals from roots
5. **Root starvation**: Lower part cannot get sugars from leaves

Enhanced Explanation: This experiment demonstrates:

- **Interdependence**: Upper and lower plant parts depend on each other
- **Phloem function**: Critical for sugar transport and plant survival
- **Source-sink relationships**: Leaves (source) must supply roots (sink)
- **Bidirectional transport**: Both xylem and phloem are essential

9. Various types of transport mechanisms are needed to fulfil the mineral requirements of a plant. Why are they not fulfilled by diffusion alone?

Solution: Limitations of simple diffusion for mineral transport:

Physical constraints:

1. **Selective membrane permeability**:
    - Lipid bilayer blocks large, polar, and charged molecules
    - Most minerals are ions that cannot cross membranes freely
    - Specific transport proteins required for each ion type
2. **Concentration gradients**:
    - Soil mineral concentrations often lower than plant needs
    - Plants require active accumulation against gradients
    - Simple diffusion cannot work uphill

Biological requirements:

1. **Selectivity needed**:
    - Plants need specific minerals in precise ratios
    - Must exclude toxic substances while accumulating nutrients
    - Different tissues have different mineral requirements
2. **Concentration requirements**:

- Some minerals needed in high concentrations (K^+, NO_3^-)
- Others required in trace amounts (Fe^{2+}, Mn^{2+}, Zn^{2+})
- Active transport enables concentration against gradients

Required transport mechanisms:

- **Facilitated diffusion**: For selective passive transport
- **Primary active transport**: Using ATP for uphill transport
- **Secondary active transport**: Using ion gradients
- **Endocytosis**: For large molecules or particles

Enhanced Explanation: Plant survival depends on acquiring minerals that are often present in low soil concentrations, requiring sophisticated transport systems that can selectively accumulate needed nutrients while excluding harmful substances.

10. How can plants be grown under limited water supply without compromising on metabolic activities?

Solution: Water conservation strategies:

1. Anti-transpirant application:

- **Abscisic acid (ABA)**: Natural hormone that closes stomata
- **Synthetic anti-transpirants**: Chemicals that reduce transpiration
- **Film-forming compounds**: Create barriers on leaf surfaces
- **Reflective coatings**: Reduce heat absorption and water loss

2. Physiological modifications:

- **Stomatal regulation**: Better control of gas exchange timing
- **Osmotic adjustment**: Accumulate solutes to maintain turgor at lower water potential
- **Root enhancement**: Deeper and more extensive root systems
- **Water storage**: Develop succulent tissues

3. Environmental management:

- **Mulching**: Reduces soil water evaporation
- **Shade provision**: Reduces heat stress and transpiration
- **Windbreaks**: Reduce wind-induced water loss
- **Humidity control**: Increase relative humidity around plants

4. Irrigation techniques:

- **Drip irrigation**: Efficient water delivery to roots
- **Subsurface irrigation**: Minimizes evaporation losses
- **Timing optimization**: Water during cooler periods
- **Water recycling**: Reuse drainage water

5. Plant breeding approaches:

- **Drought-tolerant varieties**: Genetically adapted plants
- **CAM photosynthesis**: Use CAM plants for arid conditions
- **Deep root systems**: Access deeper water sources

Enhanced Explanation: The key is optimizing the balance between water conservation and maintaining essential physiological processes like photosynthesis and mineral transport.

11. Will the ascent of sap be possible without the cohesion and adhesion of the water molecules? Explain.

Solution: No, ascent of sap would not be possible without cohesion and adhesion.

Role of cohesion:

- **Maintains water column integrity**: Hydrogen bonds between water molecules create a continuous column
- **Provides tensile strength**: Water column can withstand negative pressure (tension) up to -30 MPa
- **Prevents cavitation**: Keeps water molecules together even under high tension
- **Enables bulk flow**: Entire water column moves as a unit

Role of adhesion:

- **Anchors water to xylem walls**: Prevents water column from falling due to gravity
- **Supports capillary action**: Helps water rise in narrow xylem vessels
- **Maintains contact with vessel walls**: Ensures efficient water transport
- **Provides stability**: Keeps water column centered in vessels

Without these properties:

1. **Column breakage**: Water would separate into disconnected segments
2. **Gravitational pull**: Water would fall back down due to gravity
3. **Air bubble formation**: Cavitation would create air embolisms
4. **Transport failure**: No mechanism for long-distance water transport

Supporting evidence:

- **Xylem vessel dimensions**: Very narrow diameter (~20-200 μm) maximizes cohesive forces
- **Negative pressure measurements**: Demonstrates water under tension
- **Cavitation studies**: Show what happens when cohesion fails

Enhanced Explanation: The cohesion-tension theory explains how water can be transported to heights over 100 meters in tall trees, overcoming gravity through the combined effects of transpiration pull, water cohesion, and adhesion to vessel walls.

12. Keep some freshly cut flowers in a solution of food colour. Wait for some time for the dye to rise in the flower, when the stem of the flower is held up in light, coloured strands can be seen inside. Can this experiment demonstrate which tissue is conducting water up the stem?

Solution: Yes, this experiment clearly demonstrates xylem as the water-conducting tissue.

Experimental observations:

- **Colored strands visible**: Dye moves up specific pathways in the stem
- **Pattern distribution**: Color appears in distinct vascular bundles
- **Upward movement**: Dye travels from cut end toward petals
- **Time-dependent transport**: Progressive movement over time

What it proves:

1. **Xylem identification**: Colored strands correspond to xylem vessels

2. **Unidirectional flow**: Water moves only upward in these tissues
3. **Bulk transport**: Large volumes of water move through specific channels
4. **Living tissue requirement**: Transport stops when stem dies

Scientific principles demonstrated:

- **Transpiration stream**: Continuous water movement through xylem
- **Vascular bundle organization**: Xylem and phloem arrangement in stems
- **Tissue specialization**: Different tissues have different functions

Variations and extensions:

- **Different colored dyes**: Can trace multiple pathways
- **Time-lapse observation**: Shows transport rates
- **Cross-sectional analysis**: Reveals internal structure
- **Different plant species**: Compares vascular arrangements

Enhanced Explanation: This simple experiment provides visual evidence of water transport in plants and helps students understand the role of specialized transport tissues in plant physiology.

13. When a freshly collected Spirogyra filament is kept in a 10% potassium nitrate solution, it is observed that the protoplasm shrinks in size:

a. What is this phenomenon called? b. What will happen if the filament is replaced in distilled water?

Solution:

a. **Phenomenon: Exosmosis/Plasmolysis**

Enhanced Explanation:

- **Exosmosis**: Water moves out of the cell due to osmotic pressure
- **Plasmolysis**: The plasma membrane pulls away from the cell wall
- **Hypertonic solution**: 10% KNO_3 has higher solute concentration than cell sap
- **Water potential gradient**: Water moves from cell (higher water potential) to solution (lower water potential)

b. **Recovery in distilled water: Deplasmolysis occurs**

Process of recovery:

1. **Endosmosis begins**: Water moves into the cell from distilled water
2. **Turgor restoration**: Cell regains internal hydrostatic pressure
3. **Membrane repositioning**: Plasma membrane returns against cell wall
4. **Normal shape recovery**: Protoplasm expands to fill cell volume
5. **Metabolic resumption**: Normal cellular processes restart

Enhanced Explanation: This experiment demonstrates:

- **Reversibility**: Osmotic effects can be reversed if not prolonged
- **Semi-permeable membrane**: Cell membrane controls water movement
- **Osmotic principles**: Water moves according to water potential gradients
- **Cell wall protection**: Rigid cell wall prevents complete cell collapse

14. Sugar crystals do not dissolve easily in ice-cold water. Explain

Solution: Temperature effects on dissolution:

Kinetic molecular theory explanation:

- **Reduced molecular motion**: Cold water molecules move slower
- **Lower collision frequency**: Fewer water molecules strike sugar crystals per unit time
- **Decreased energy**: Insufficient kinetic energy to break sugar-sugar bonds
- **Reduced solvent power**: Water's ability to surround and separate sugar molecules decreases

Thermodynamic factors:

1. **Activation energy**: Dissolution requires minimum energy to break crystal lattice
2. **Temperature dependence**: Higher temperature provides more thermal energy
3. **Entropy effects**: Molecular disorder increases with temperature
4. **Heat of solution**: Energy needed to separate solute molecules

Practical implications:

- **Solubility curves**: Most substances show increased solubility with temperature
- **Industrial processes**: Many use heat to increase dissolution rates
- **Biological systems**: Enzyme activity and metabolic rates temperature-dependent
- **Food preparation**: Hot beverages dissolve sugar more readily

Enhanced Explanation: This principle explains why hot tea or coffee dissolves sugar instantly while cold drinks require stirring and time. The relationship between temperature and dissolution rate is fundamental to many physical and biological processes.

15. Salt is applied to tennis lawns to kill weeds. How does salting tennis lawns help in the killing of weeds without affecting the grass?

Solution: Osmotic weed control mechanism:

How salt kills weeds:

1. **Hypertonic soil solution**: High salt concentration creates osmotic stress
2. **Exosmosis**: Water moves out of plant roots into soil
3. **Cellular dehydration**: Plant cells lose turgor and shrink
4. **Metabolic disruption**: Essential processes shut down
5. **Plant death**: Severe water loss causes mortality

Why grass survives better:

1. **Salt tolerance**: Many grass species have moderate salt tolerance
2. **Root depth**: Deeper roots access less salty water layers
3. **Recovery ability**: Grasses can regrow from underground parts
4. **Osmotic adjustment**: Better ability to accumulate compatible solutes
5. **Selective application**: Salt can be applied more precisely to weed areas

Application method:

- **Concentration**: Typically 1 cup salt in 2 cups water
- **Timing**: Apply during hot, sunny weather for maximum effect
- **Precision**: Target weed areas specifically
- **Follow-up**: May require repeated applications

Environmental considerations:
- **Soil health**: Excessive salt can damage soil structure
- **Water contamination**: Salt can leach into groundwater
- **Non-selective nature**: Will harm any plants at high concentrations

Enhanced Explanation: This method works on the principle that weeds generally have lower salt tolerance than established grass, but it should be used carefully to avoid long-term soil damage.

16. What is the chemical composition of xylem and phloem sap?

Solution:

Xylem sap composition:
- **Water**: 95-99% of content
- **Inorganic minerals**:
  - Macronutrients: N, P, K, Ca, Mg, S
  - Micronutrients: Fe, Mn, Zn, Cu, B, Mo, Cl
- **pH**: Mildly acidic (5.0-6.5)
- **Organic compounds**: Small amounts of organic acids, amino acids
- **Hormones**: Cytokinins, gibberellins (trace amounts)

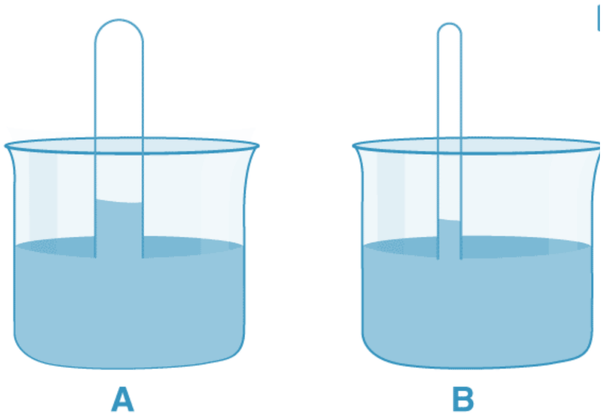
Phloem sap composition:
- **Water**: 80-90% of content
- **Sugars**:
  - **Primary**: Sucrose (10-25%)
  - **Secondary**: Glucose, fructose, raffinose, stachyose
- **Organic compounds**:
  - Amino acids and proteins
  - Organic acids
  - Plant hormones (auxins, cytokinins, gibberellins, ABA)
- **Minerals**: Lower concentrations than xylem
- **pH**: Alkaline (7.5-8.5)

Functional differences:

Aspect	**Xylem Sap**	**Phloem Sap**
Primary function	Water and mineral transport	Sugar and organic transport
Direction	Unidirectional (upward)	Bidirectional
Concentration	Dilute	Concentrated
Transport mechanism	Transpiration pull	Mass flow/pressure flow

Enhanced Explanation: The different compositions reflect their specialized functions: xylem for efficient water and mineral transport, phloem for energy-rich organic compound distribution throughout the plant.

17. Observe the figure and answer the question provided below the figure.



[Figure shows two tubes A and B with different diameters in water]

Why does tube B show higher water rise than A?

Solution: Capillary action principles:

Why tube B (narrower) shows higher rise:

1. **Surface area relationship**: Smaller diameter = less surface area at meniscus
2. **Meniscus curvature**: More curved in narrow tube
3. **Surface tension effects**: Greater relative effect in smaller diameter
4. **Adhesive forces**: More significant in narrow spaces
5. **Gravitational opposition**: Less water volume to support

Mathematical relationship: **$h = (2\gamma\cos\theta)/(\rho gr)$**

Where:

- h = height of rise
- γ = surface tension
- θ = contact angle
- ρ = density of liquid
- g = gravitational acceleration
- r = radius of tube

Key insight: Height is inversely proportional to radius ($h \propto 1/r$)

Biological significance:

- **Plant xylem**: Narrow vessels enhance capillary rise
- **Root hair structure**: Fine diameter increases water uptake
- **Soil water movement**: Capillary action in soil pores
- **Transpiration enhancement**: Works with other forces for water transport

Enhanced Explanation: This demonstrates why plants have evolved narrow xylem vessels and why capillary action contributes significantly to water transport in plants, especially in smaller vessels and during initial water uptake.

18. What are 'aquaporins'? How does the presence of aquaporins affect osmosis?

Solution: Aquaporins definition and structure:

- **Water channel proteins**: Specialized integral membrane proteins
- **Selective permeability**: Allow only water molecules to pass

- **Tetrameric structure**: Four identical subunits form functional channel
- **Size selectivity**: Channel diameter ~2.8 Å (perfect for water molecules)
- **Charge selectivity**: Exclude ions while allowing water

Types and distribution:

1. **PIP1 and PIP2**: Plasma membrane intrinsic proteins
2. **TIP**: Tonoplast intrinsic proteins (vacuolar membrane)
3. **NIP**: NOD26-like intrinsic proteins
4. **SIP**: Small basic intrinsic proteins

Effects on osmosis:

Enhanced water permeability:

- **Increased rate**: 10-100 fold increase in water transport rate
- **Maintained selectivity**: Still excludes solutes and ions
- **Bidirectional transport**: Water can move both directions as needed
- **Rapid equilibration**: Faster approach to osmotic equilibrium

Regulatory mechanisms:

- **Gating**: Can open/close in response to pH, calcium, phosphorylation
- **Expression regulation**: Aquaporin production varies with conditions
- **Subcellular localization**: Different types in different membranes

Biological significance:

1. **Plant water relations**: Critical for rapid water movement
2. **Stress response**: Help plants respond to water stress
3. **Organ development**: Important for cell expansion
4. **Root water uptake**: Essential for efficient water absorption

Enhanced Explanation: Aquaporins represent a perfect example of how evolution has solved the problem of selective, rapid water transport across biological membranes while maintaining ionic selectivity.

19. ABA (Abscisic acid) is called a stress hormone.

a. How does this hormone overcome stress conditions? b. From where does this hormone gets released in leaves?

Solution:

a. **How ABA overcomes stress conditions:**

Water stress responses:

1. **Stomatal closure**:
    - Triggers K^+ efflux from guard cells
    - Reduces turgor pressure in guard cells
    - Minimizes water loss through transpiration
    - Maintains plant water balance
2. **Root growth promotion**:
    - Stimulates root elongation and branching
    - Increases water absorption capacity

   - Helps plants access deeper water sources
3. **Metabolic adjustments**:
   - Induces synthesis of stress proteins
   - Promotes osmotic adjustment compounds
   - Enhances antioxidant enzyme activity
   - Protects cellular components from damage
4. **Developmental adaptations**:
   - **Seed dormancy**: Prevents germination under unfavorable conditions
   - **Bud dormancy**: Suspends growth during adverse conditions
   - **Senescence regulation**: Controls aging processes

Other stress responses:

- **Salt stress**: Helps exclude Na^+ and accumulate K^+
- **Cold stress**: Induces cold-responsive genes
- **Pathogen stress**: Enhances disease resistance mechanisms

b. **ABA release sites in leaves:**

Primary source: **Mesophyll cells of leaves**

- Chloroplast precursors synthesized in plastids
- Final steps occur in cytoplasm
- Released in response to water stress signals

Secondary sources:

- **Vascular parenchyma**: Cells surrounding veins
- **Guard cells**: Can synthesize ABA locally
- **Root-derived ABA**: Transported to leaves via xylem

Synthesis pathway: Zeaxanthin → Violaxanthin → Neoxanthin → ABA-aldehyde → ABA

Enhanced Explanation: ABA acts as a chemical messenger that coordinates whole-plant responses to stress, integrating information about environmental conditions and adjusting plant physiology accordingly. Its production in mesophyll cells allows rapid local responses to leaf water status.

20. We know that plants are harmed by excess water. But plants survive under flooded condition. How are they able to manage excess water?

Solution: Problems with excess water:

- **Oxygen deprivation**: Waterlogged soils lack oxygen for root respiration
- **Anaerobic conditions**: Lead to toxic metabolite accumulation
- **Reduced nutrient uptake**: Impaired root function affects mineral absorption
- **Root damage**: Prolonged flooding can kill root tissues

Survival adaptations in flood-tolerant plants:

Anatomical adaptations:

1. **Aerenchyma development**:
   - Air-filled spaces in roots and stems
   - Allow oxygen transport from shoots to roots

   - Provide buoyancy for aquatic parts
2. **Adventitious roots**:
   - New roots develop from stems above water
   - Replace damaged submerged roots
   - Access atmospheric oxygen
3. **Pneumatophores**:
   - Aerial roots in some species (mangroves)
   - Specialized for gas exchange
   - Allow root respiration in waterlogged conditions

Physiological adaptations:

1. **Anaerobic respiration enhancement**:
   - Increased fermentation pathways
   - Alcohol and lactate production
   - Maintains ATP production without oxygen
2. **Metabolic adjustments**:
   - Reduced metabolic rate during flooding
   - Efficient use of stored carbohydrates
   - Protection against toxic metabolites
3. **Hormonal responses**:
   - Ethylene production in flooded conditions
   - Triggers aerenchyma formation
   - Promotes adaptive growth responses

Biochemical adaptations:

- **Antioxidant systems**: Combat oxidative stress during re-oxygenation
- **Compatible solutes**: Maintain osmotic balance
- **Stress proteins**: Protect cellular components

Enhanced Explanation: Flood-tolerant plants have evolved multiple coordinated strategies that allow them to maintain cellular respiration and prevent toxic accumulation during periods of excess water, demonstrating remarkable physiological plasticity.

21. Differentiate between diffusion and translocation in plants.

Solution:

Aspect	Diffusion	Translocation
Definition	Movement of substances from higher to lower concentration	Bulk transport of materials through specialized plant channels
Distance	Short distances (cellular level)	Long distances (organ to organ)
Mechanism	Random molecular motion	Mass flow in vascular tissues
Energy requirement	No external energy needed	May require energy for loading/unloading

Aspect	Diffusion	Translocation
Direction	Along concentration gradient	Can be against gradient
Speed	Relatively slow	Rapid bulk movement
Tissues involved	Any tissue	Primarily xylem and phloem
Substances transported	Small molecules, ions, gases	Water, minerals, sugars, hormones
Selectivity	Non-selective	Highly selective
Examples	O_2, CO_2 exchange in leaves	Sugar transport from leaves to roots

Detailed explanations:

Diffusion characteristics:

- **Passive process**: Driven by kinetic energy of molecules
- **Equilibrium tendency**: Continues until uniform distribution
- **Membrane dependence**: Rate affected by membrane permeability
- **Distance limitation**: Effective only over short distances

Translocation characteristics:

- **Active process**: Often requires metabolic energy
- **Directional flow**: From source to sink organs
- **Vascular dependence**: Requires specialized transport tissues
- **Long-distance efficiency**: Can transport over meters in tall trees

Enhanced Explanation: While diffusion handles local cellular transport, translocation manages the plant's long-distance transport needs, enabling coordination between different plant organs and tissues.

22. How is facilitated diffusion different from diffusion?

Solution:

Aspect	Simple Diffusion	Facilitated Diffusion
Pathway	Through phospholipid bilayer	Through membrane proteins
Selectivity	Non-selective for small, lipophilic molecules	Highly selective for specific substances
Proteins required	No proteins needed	Requires transport proteins
Saturation	No saturation kinetics	Shows saturation at high concentrations
Competition	No competitive inhibition	Competitive inhibition possible
Rate	Relatively slow for polar molecules	Can be very rapid
Examples	O_2, CO_2, ethanol	Glucose, ions, water (through aquaporins)

Types of transport proteins in facilitated diffusion:

1. **Channel proteins**:
   - **Ion channels**: Selective for specific ions (Na^+, K^+, Ca^{2+}, Cl^-)
   - **Aquaporins**: Water-specific channels
   - **Porins**: Large molecules in outer membranes
2. **Carrier proteins**:
   - **GLUT proteins**: Glucose transporters
   - **Amino acid transporters**: Various amino acid carriers
   - **Nucleotide transporters**: For ATP, ADP transport

Kinetic differences:
Simple diffusion: Rate ∝ Concentration (linear relationship)
Facilitated diffusion: Rate follows Michaelis-Menten kinetics
- **Vmax**: Maximum transport rate (when all carriers saturated)
- **Km**: Concentration at half-maximum rate
- **Saturation**: Rate plateaus at high concentrations

Enhanced Explanation: Facilitated diffusion combines the energy efficiency of passive transport with the selectivity of active transport, allowing cells to rapidly transport specific molecules without energy expenditure while maintaining selective control over what crosses the membrane.

23. Explain the mass flow hypothesis of transport in phloem
Solution: Mass Flow Hypothesis (Münch, 1930):
Basic principle: Phloem transport is driven by pressure differences between source and sink, created by osmotic pressure gradients.
Mechanism steps:
1. **Source (photosynthetic tissues)**:
   - **Sugar production**: Photosynthesis produces glucose
   - **Sucrose formation**: Glucose converted to sucrose for transport
   - **Active loading**: Sucrose actively transported into sieve tubes
   - **Osmotic pressure increase**: High sucrose concentration lowers water potential
   - **Water influx**: Water enters from adjacent xylem via osmosis
   - **Positive pressure**: Creates high hydrostatic pressure in phloem
2. **Sink (consuming/storage tissues)**:
   - **Sugar unloading**: Sucrose actively removed from sieve tubes
   - **Osmotic pressure decrease**: Lower sucrose concentration increases water potential
   - **Water efflux**: Water moves back to xylem
   - **Negative pressure**: Creates low hydrostatic pressure
3. **Bulk flow**:
   - **Pressure gradient**: High pressure at source, low at sink
   - **Mass movement**: Entire solution flows from high to low pressure

    - **Bidirectional capacity**: Flow direction depends on source-sink locations

Supporting evidence:

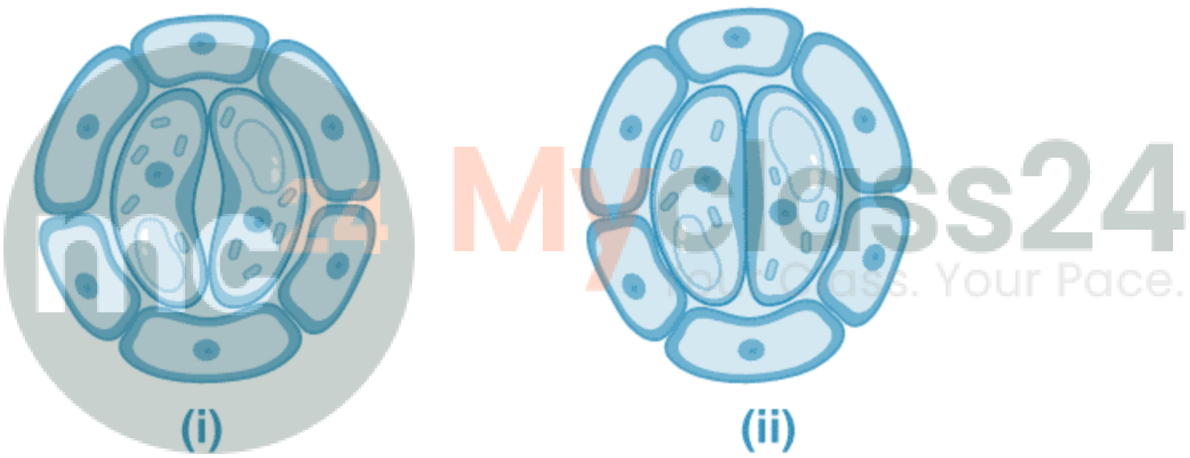
- **Aphid stylet experiments**: Direct measurement of phloem pressure
- **Pressure measurements**: Demonstrate pressure gradients in phloem
- **Loading/unloading studies**: Confirm active transport at source and sink
- **Seasonal changes**: Flow direction changes with source-sink relationships

Seasonal variations:

- **Growing season**: Leaves (source) → Roots, fruits (sink)
- **Spring mobilization**: Storage organs (source) → Growing shoots (sink)
- **Senescence**: Old leaves (source) → Young leaves, storage organs (sink)

Enhanced Explanation: The mass flow hypothesis elegantly explains how plants can transport large quantities of organic materials efficiently over long distances, with the direction and rate of transport determined by the metabolic activities and needs of different plant parts.

24. Observe the diagram and answer the following:



a. Are these types of guard cells found in monocots or dicots? b. Which of these shows a higher water content (i) or (ii)? c. Which element plays an important role in the opening and closing of stomata?

[Figure shows two guard cell diagrams showing different turgor states]

Solution:

a. **Guard cell type: Dicots**

Enhanced Explanation:

- **Bean-shaped guard cells**: Characteristic of dicotyledonous plants
- **Monocot guard cells**: Typically dumbbell-shaped or elongated
- **Cell wall thickening**: Uneven thickening creates the kidney bean shape
- **Functional significance**: Shape change enables stomatal opening/closing

b. **Higher water content: Figure (i)**

Enhanced Explanation: Figure (i) shows:

- **Turgid guard cells**: High water content creates turgor pressure
- **Open stomata**: Turgor pressure forces cells to bend outward
- **Functional state**: Allows gas exchange for photosynthesis

Figure (ii) shows:

- **Flaccid guard cells**: Low water content, reduced turgor
- **Closed stomata**: Cells collapse inward, closing the pore
- **Conservation mode**: Prevents water loss

c. **Key element: Potassium ion (K^+)**

Enhanced Explanation: Potassium's role in stomatal movement:

Opening mechanism:

1. **K^+ influx**: Active transport of K^+ into guard cells
2. **Osmotic adjustment**: Increases osmotic pressure inside cells
3. **Water influx**: Water follows K^+ into cells via osmosis
4. **Turgor increase**: Rising pressure forces cells to swell and bend
5. **Stomatal opening**: Pore opens for gas exchange

Closing mechanism:

1. **K^+ efflux**: K^+ actively transported out of guard cells
2. **Osmotic decrease**: Reduces osmotic pressure
3. **Water efflux**: Water leaves cells following osmotic gradient
4. **Turgor loss**: Cells lose pressure and collapse inward
5. **Stomatal closure**: Pore closes to prevent water loss

Regulation factors:

- **Light**: Stimulates K^+ influx and opening
- **CO_2 levels**: Low CO_2 promotes opening
- **Water status**: Water stress triggers closure
- **Circadian rhythm**: Daily opening/closing cycles

25. Define Uniport, Symport and Antiport. Do they require energy?

Solution:

Transport type definitions:

1. **Uniport**:
   - **Definition**: Single substance moves in one direction across membrane
   - **Mechanism**: Independent transport of one molecule/ion type
   - **Examples**: Glucose transport via GLUT proteins, K^+ channels
   - **Directionality**: Follows electrochemical gradient
2. **Antiport**:
   - **Definition**: Two substances move in opposite directions
   - **Mechanism**: One substance's movement coupled to another in reverse
   - **Examples**: Na^+-K^+ ATPase, Na^+-Ca^{2+} exchanger, Na^+-H^+ antiporter
   - **Function**: Often maintains ionic balance
3. **Symport**:

  - **Definition**: Two substances move in the same direction
  - **Mechanism**: One substance's transport drives another's movement
  - **Examples**: Na^+-glucose cotransporter, Na^+-amino acid transporters
  - **Function**: Often accumulates nutrients against gradients

Energy requirements:

Direct energy requirement: No

- None of these mechanisms directly require ATP
- They can function as passive or secondary active transport

Indirect energy relationships:

1. **Primary active transport**: Uses ATP directly (Na^+-K^+ ATPase)
2. **Secondary active transport**: Uses energy stored in gradients
   - **Symport/Antiport**: Often driven by Na^+ or H^+ gradients
   - **Gradient maintenance**: Requires primary active transport

Examples by energy type:

Passive (no energy):

- Uniport: Ion channels following gradients
- Antiport: Some exchangers following gradients

Secondary active (indirect energy):

- Symport: Na^+-glucose cotransporter (uses Na^+ gradient)
- Antiport: Na^+-Ca^{2+} exchanger (uses Na^+ gradient)

Enhanced Explanation: While these transport mechanisms don't directly consume ATP, many function as part of energy-coupled systems that ultimately depend on primary active transport to maintain the driving gradients.