Diffusion and Osmosis:
How Things Cross Cell Membranes

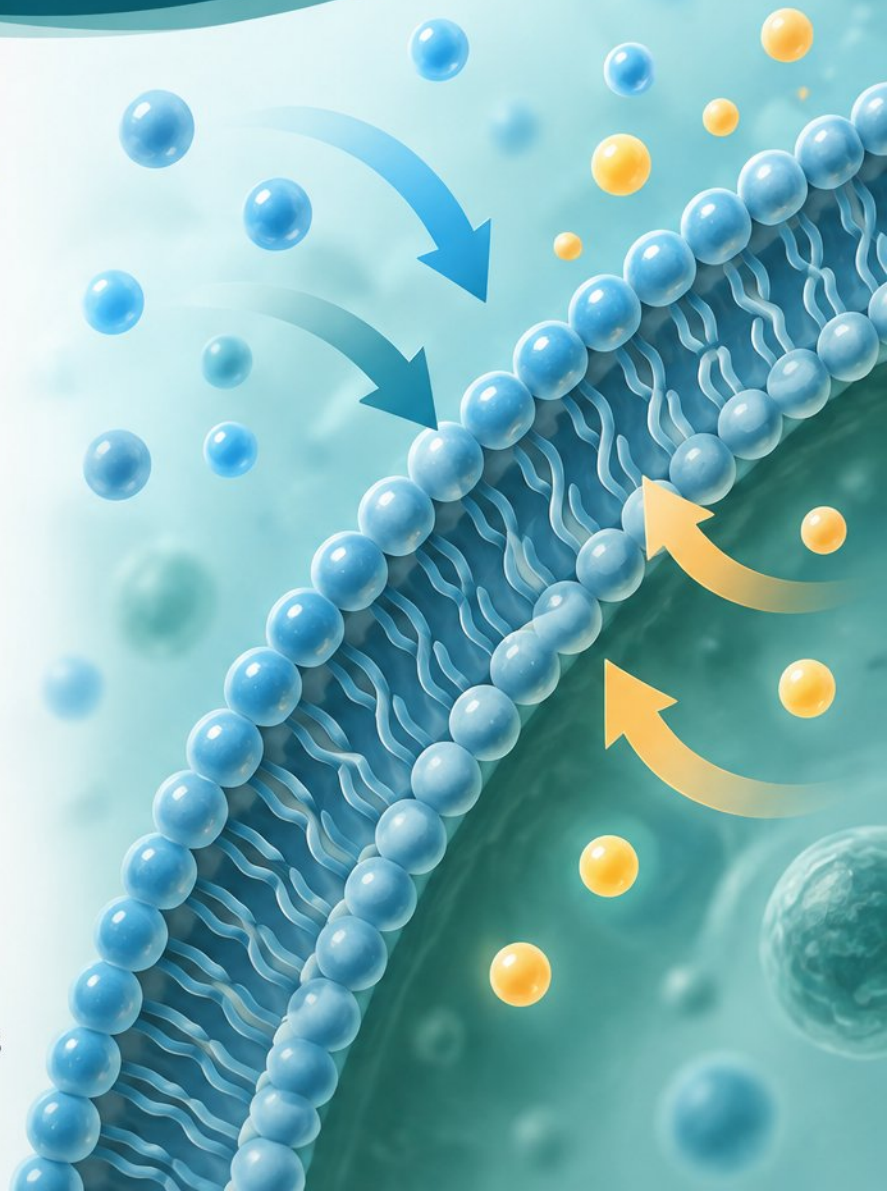
Roadmap: membrane structure, diffusion, osmosis, water potential, tonicity, active and bulk transport, investigations, teaching applications

Why it matters: explain everyday, clinical, and classroom phenomena with confidence

Misconceptions we will confront: cells as simple bags, water "wanting" to move, molecules stopping at equilibrium

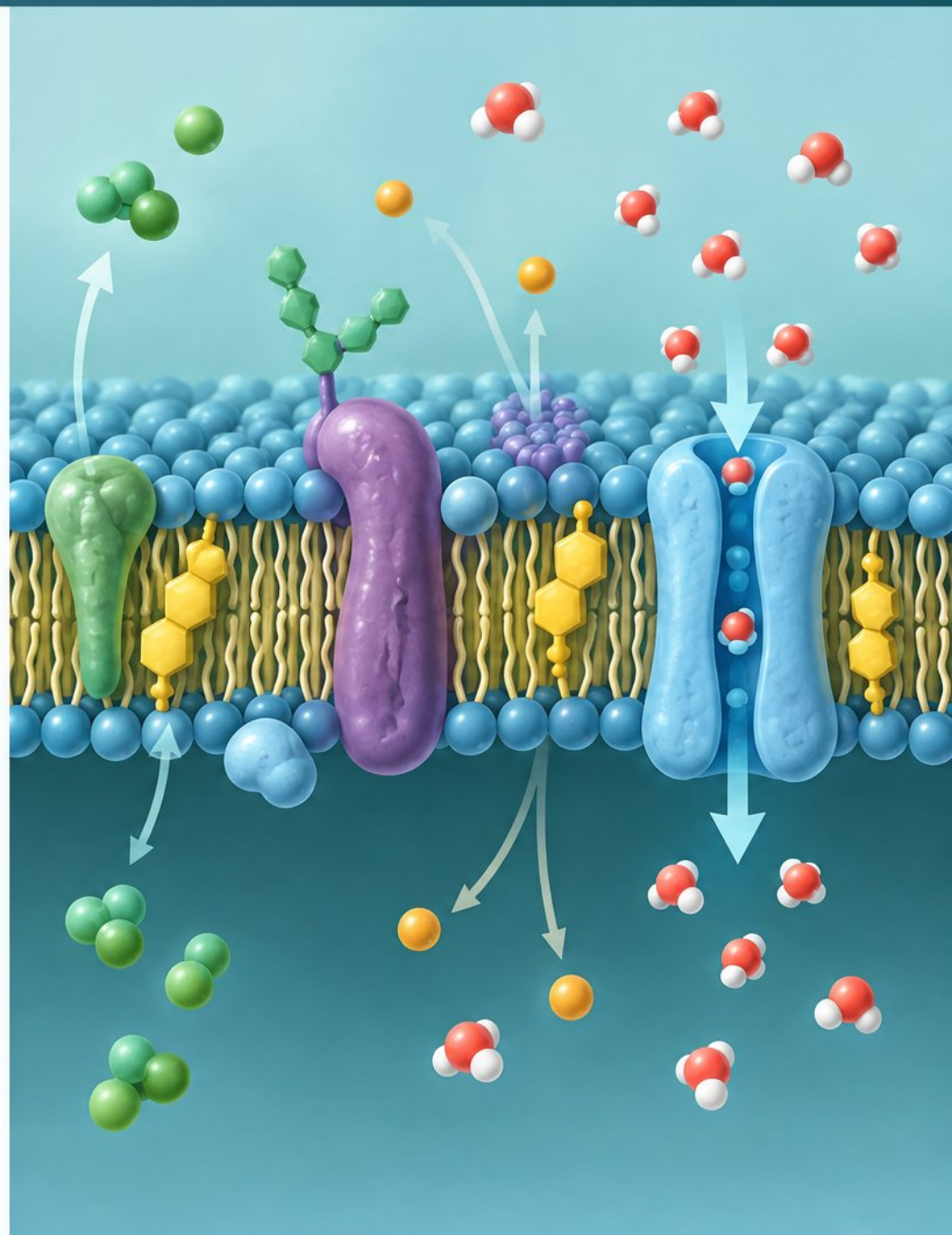
Learning outcomes: predict direction and rate of solute and water movement

Interpret tonicity and osmolarity, analyze transport experiments, design demonstrations

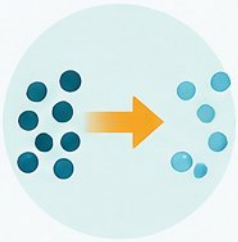


Membrane Structure and Selective Permeability

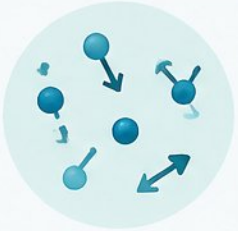
- **Phospholipid bilayer:** amphipathic lipids form a hydrophobic core in water
- **Fluid mosaic model:** proteins, cholesterol, glycoproteins, lipid rafts, dynamic asymmetry
- **Selective permeability:** small nonpolar molecules cross freely; ions and polar molecules need proteins
- **Aquaporins** provide the main fast route for water
- **Water permeability** varies widely among cell types



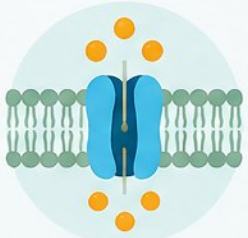
Diffusion: Random Motion and the Power of Gradients



Net movement from higher to lower concentration; random thermal motion drives it



At equilibrium, molecules keep moving with no net change



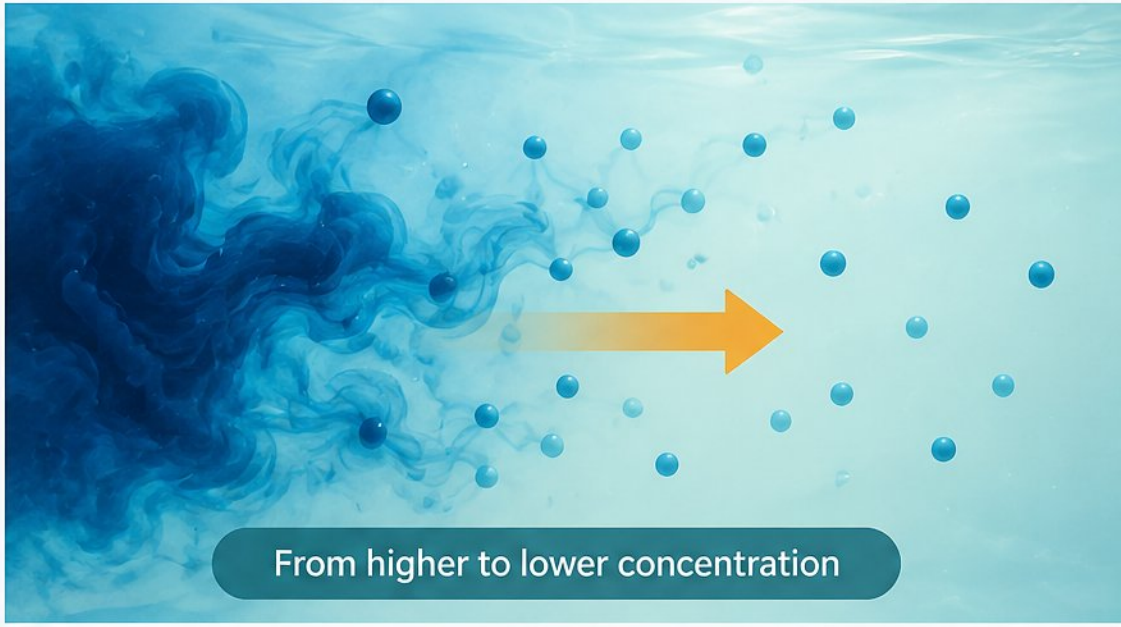
No ATP needed: simple diffusion through lipid bilayer, facilitated via channels and carriers

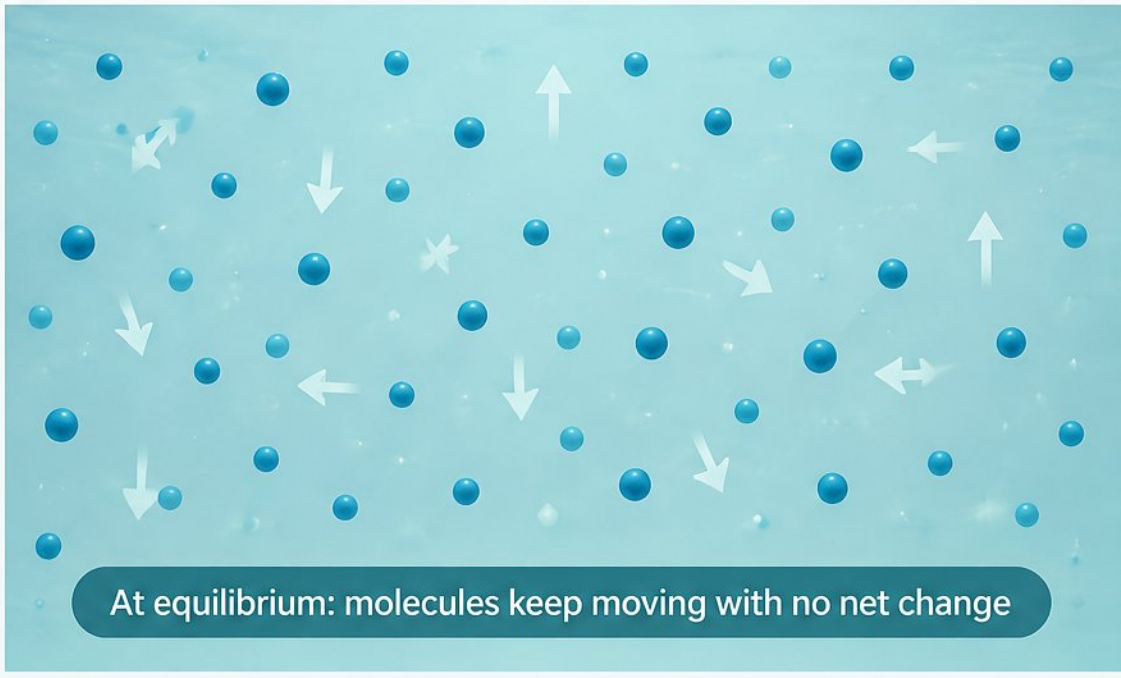


Fick's law: rate depends on gradient, surface area, distance, size, and charge



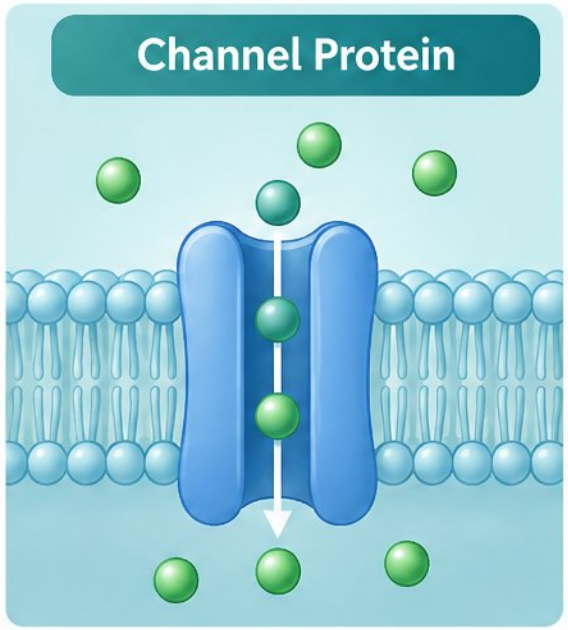
Everyday examples: O_2/CO_2 exchange in lungs, dye spreading, glucose uptake

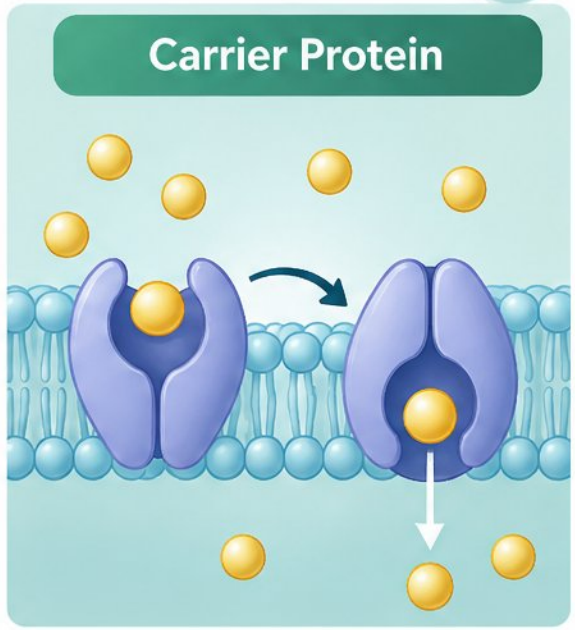


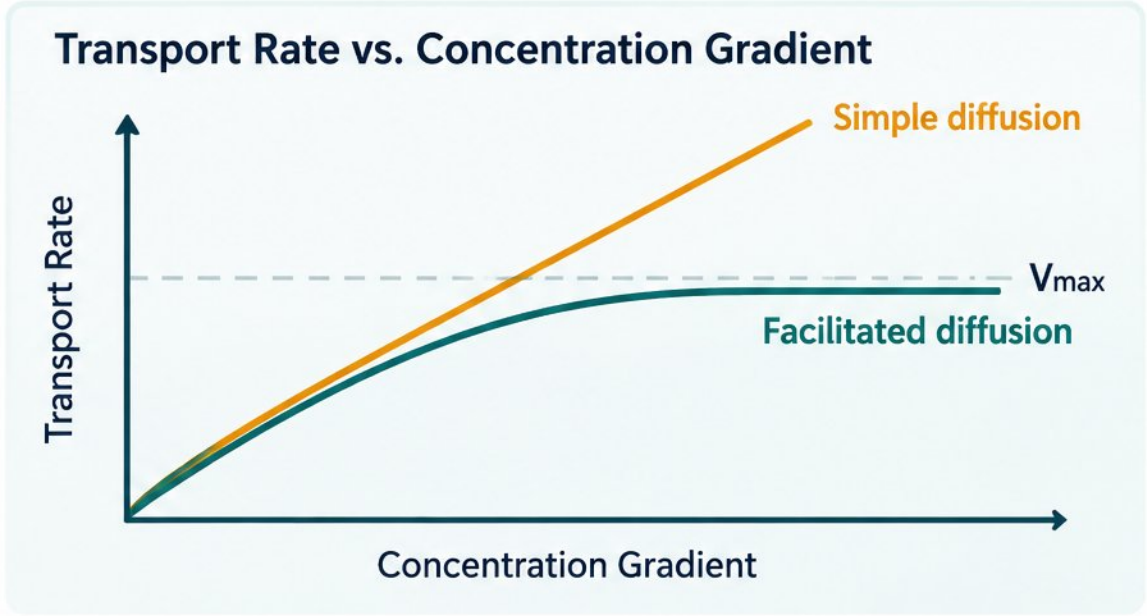


Facilitated Diffusion: Channels, Carriers, and Saturation

- Channel proteins form selective pores; carriers bind solutes and change shape to move them
- Passive like simple diffusion—no ATP required; solutes move down their concentration gradient
- Carrier-mediated transport shows specificity and saturation: rate rises then plateaus at Vmax
- Simple diffusion keeps rising with gradient; facilitated diffusion levels off when all carriers are occupied
- Biological examples: GLUT glucose transporters; ion channels in nerve signaling
- Misconception check: saturation reflects limited carriers, not energy input

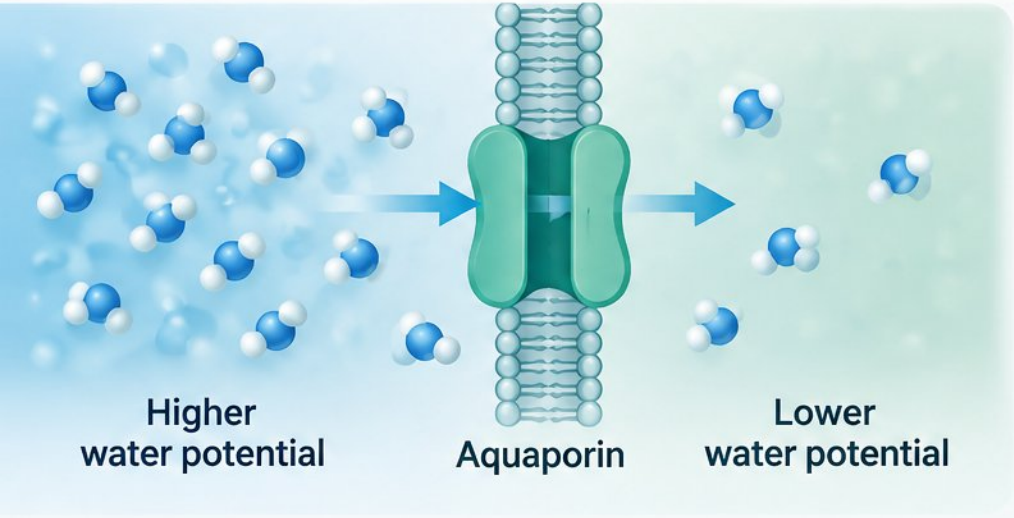


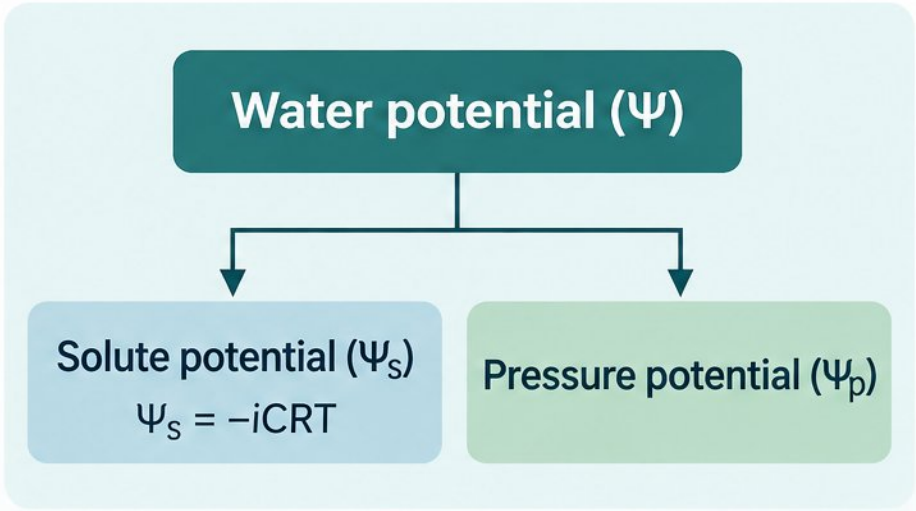


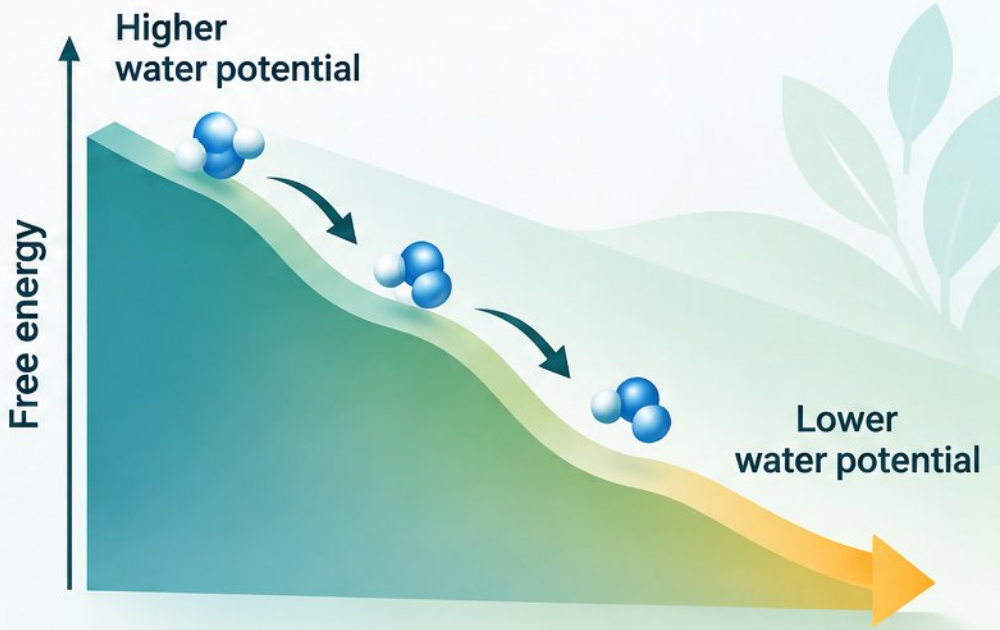


Osmosis and Water Potential: Beyond 'Water Wants to Move'

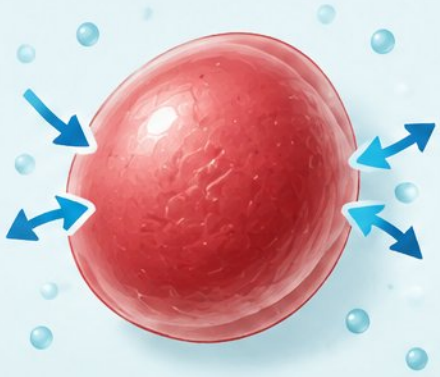
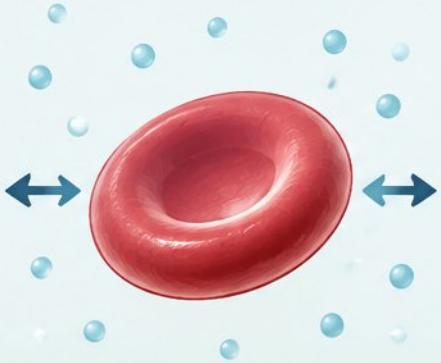
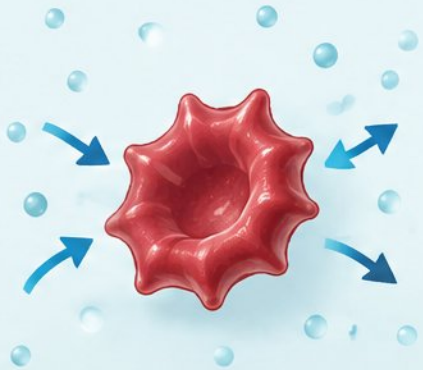
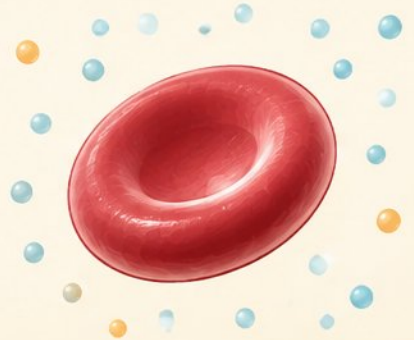
- Osmosis: water crosses a selectively permeable membrane from higher to lower water potential
- Water potential (Ψ) = solute potential (Ψ_s) + pressure potential (Ψ_p)
- $\Psi_s = -iCRT$; solutes lower Ψ, as in the van 't Hoff relationship
- Water moves down a free-energy gradient — not because it 'prefers' solute
- Aquaporins boost water permeability and are regulated in plants and animals







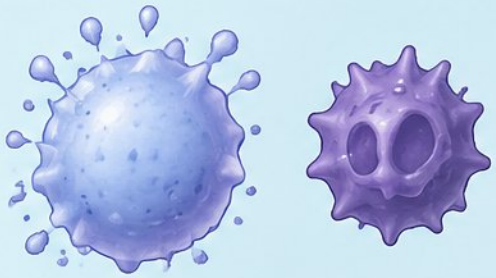
Tonicity vs. Osmolarity: Predicting Cell Volume

Hypotonic	Isotonic	Hypertonic	Isosmotic solutions can be hypotonic
			
Water enters cell	No net change in cell volume	Water leaves cell	Urea, 5% dextrose in water

- Osmolarity = total solute particles; tonicity = effect on cell volume
- Tonicity depends on nonpenetrating solutes and membrane permeability
- Isosmotic solutions can be hypotonic: urea, 5% dextrose in water
- Hypotonic → water enters; hypertonic → water leaves; isotonic → no net change
- **Pitfall:** assuming tonicity can be read directly from osmolarity

Cell Responses Across Kingdoms: Lysis, Turgor, and Plasmolysis

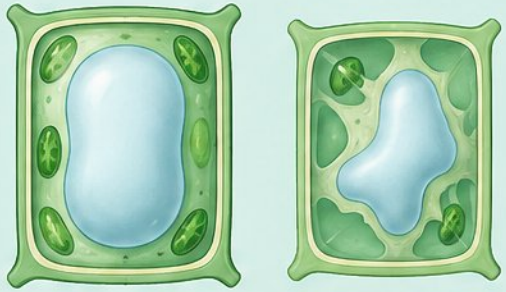
Animal cells



Lysis
(hypotonic)

Crenation
(hypertonic)

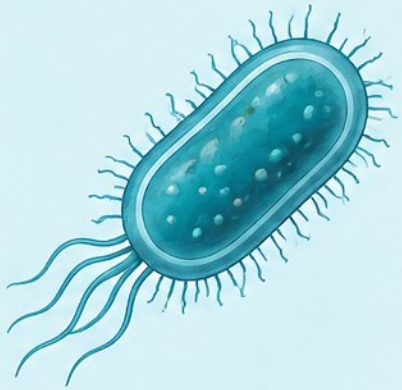
Plant cells



Turgid

Plasmolyzed
(water loss)

Bacterial cell



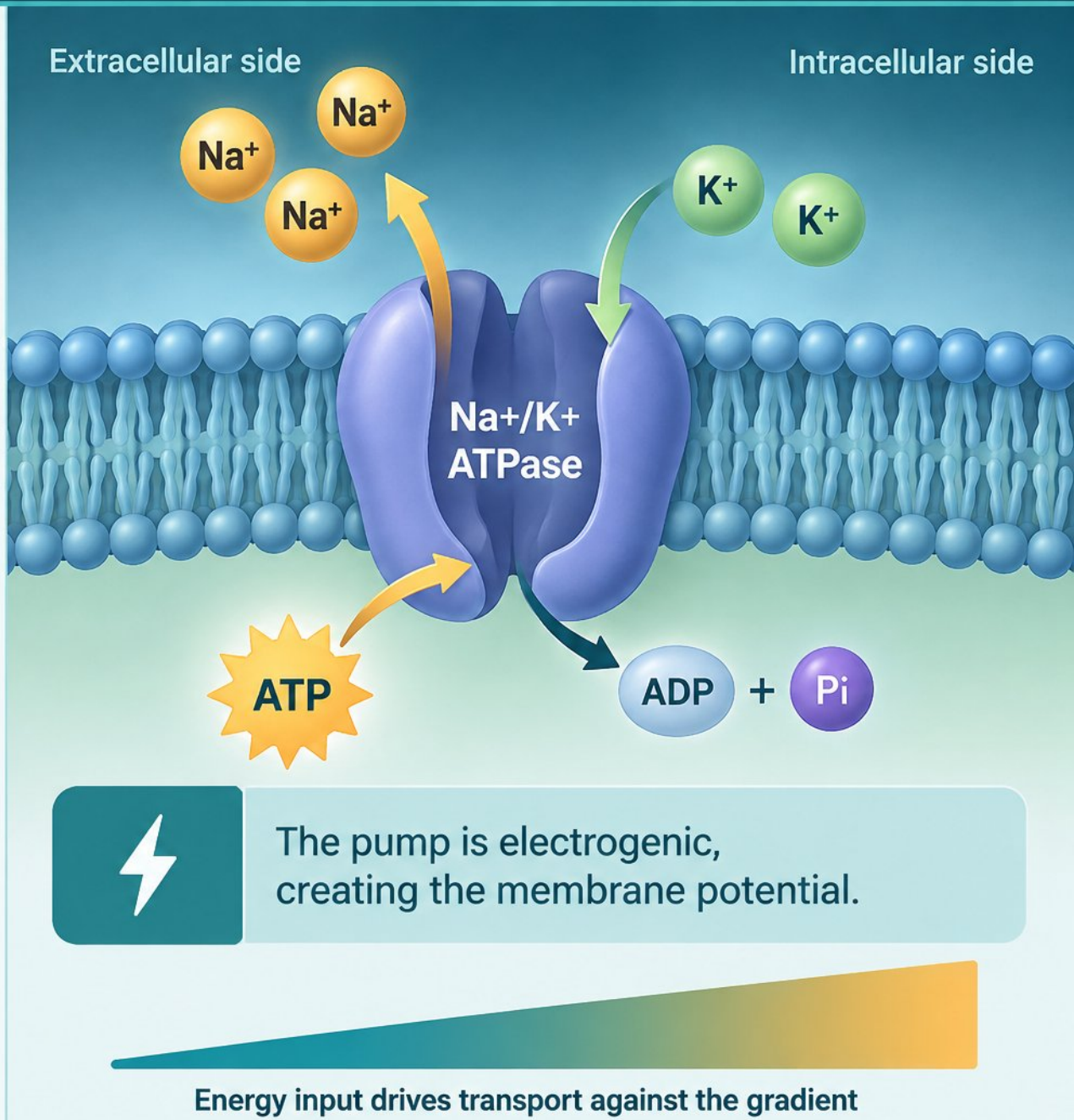
Fungal cell



- **Animal cells:** lysis in hypotonic environments; crenation in hypertonic ones
- **Plant cells:** cell wall limits expansion, building turgor pressure; water loss causes plasmolysis and wilting
- **Bacterial and fungal cells:** cell walls, halotolerance, and osmotic stress responses
- **Osmoregulation:** osmoregulators vs. osmoconformers; freshwater and marine examples
- **Clinical and food-science links:** IV fluid choice, tissue preservation, salting and sugaring food

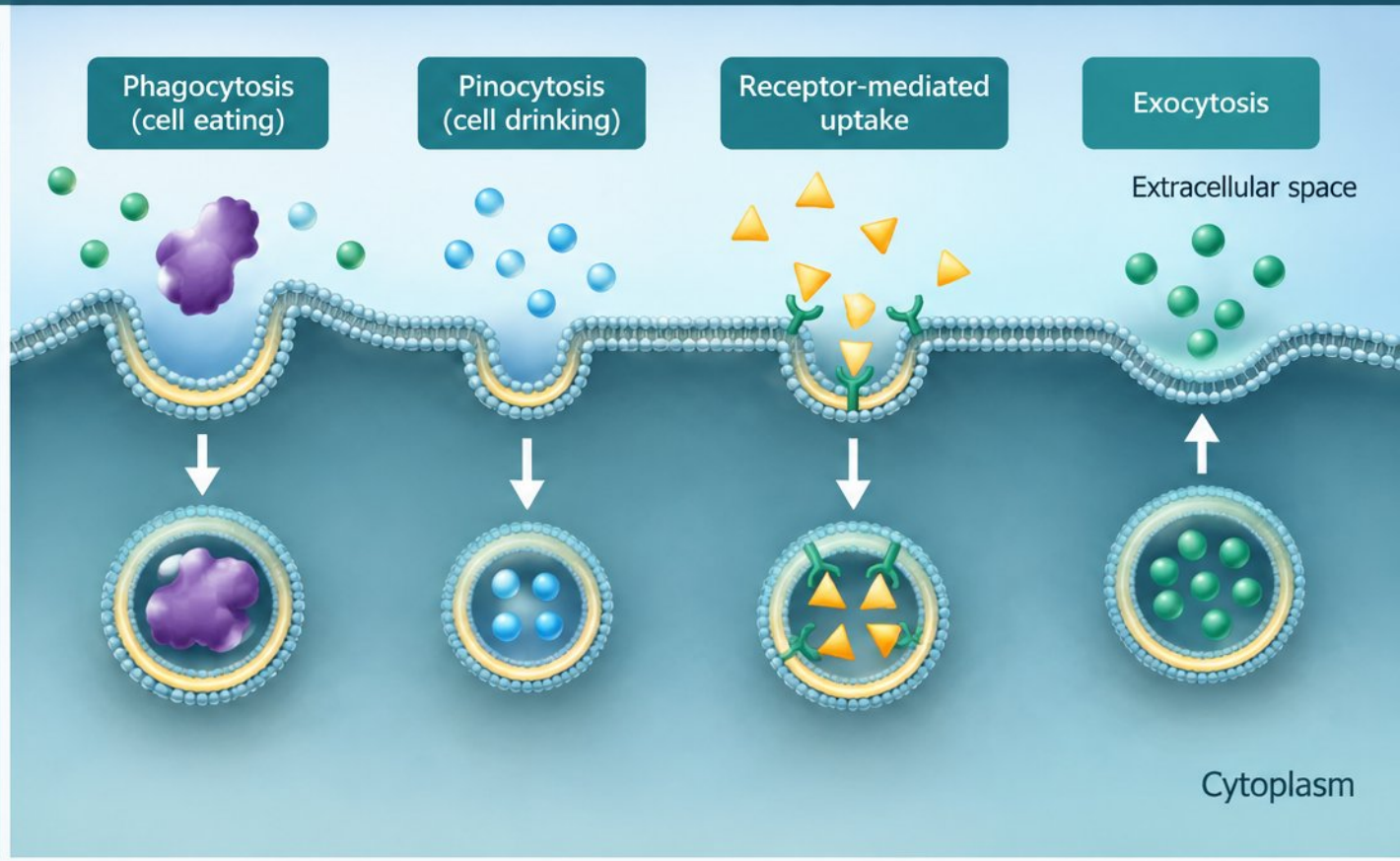
Active Transport: Pumps That Work Against the Gradient

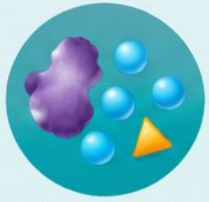
- Passive transport cannot maintain ion gradients or accumulate nutrients
- Primary active transport: ATP-driven Na+/K+ ATPase pumps 3 Na+ out, 2 K+ in
- The pump is electrogenic, creating the membrane potential
- Secondary active transport: symport and antiport harness the Na+ gradient
- Examples: nerve signaling, SGLT1 glucose uptake, kidney reabsorption
- Energy, directionality, and specificity separate active transport from diffusion



Bulk Transport: Endocytosis and Exocytosis

- Vesicles move large molecules, particles, and membrane itself
- Endocytosis: phagocytosis (cell eating), pinocytosis (cell drinking), receptor-mediated uptake
- Exocytosis: vesicle fusion releases secretions and recycles membrane
- LDL receptor defects in familial hypercholesterolemia cause dangerous cholesterol buildup
- All vesicular transport requires ATP, unlike passive diffusion

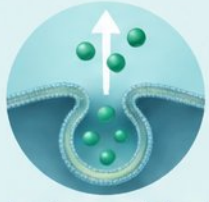




Moves large molecules, particles, and membrane itself



Endocytosis: phagocytosis (cell eating), pinocytosis (cell drinking), receptor-mediated uptake



Exocytosis: vesicle fusion releases secretions and recycles membrane



All vesicular transport requires ATP, unlike passive diffusion

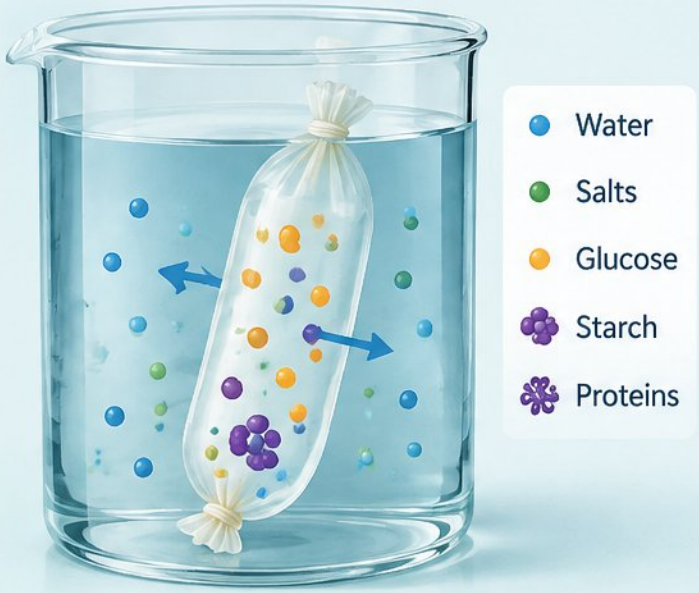


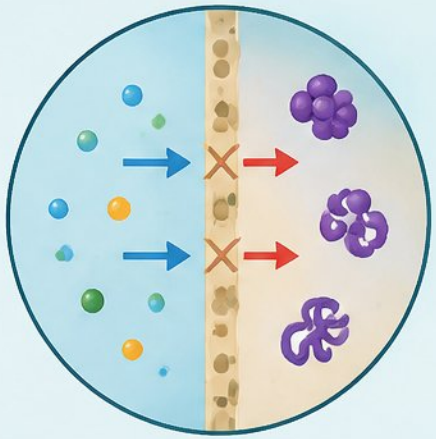
LDL receptor defects in familial hypercholesterolemia cause dangerous cholesterol buildup

Investigating Transport: Classic Experiments and Data

- **Dialysis tubing model cells:** pores pass water, salts, glucose—but not starch or proteins
- **Plant plasmolysis labs:** *Elodea*, red onion, and potato osmometer protocols
- **Experimental design:** controls, variables, replicates; safe salt and sucrose handling
- **Quantitative analysis:** mass or volume change, percentage change, hemolysis assays, cell counts
- **Graphs:** concentration vs. mass change reveals the isotonic point

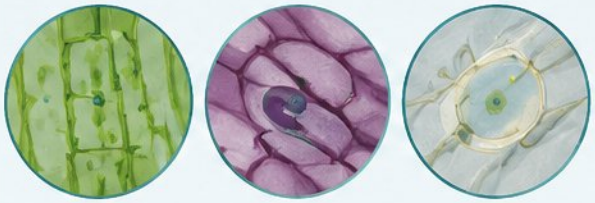
% Change = [(Final – Initial) / Initial] × 100





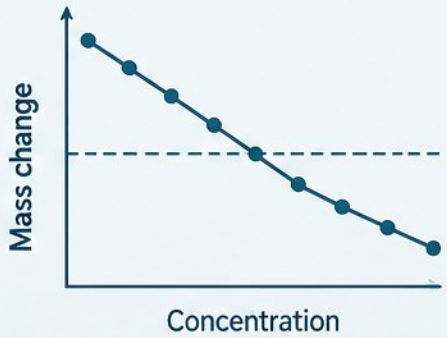
Two-compartment membrane model

Plant Plasmolysis Labs



Elodea | Red onion | Potato osmometer

Mass Change Graph



SAME PRINCIPLES. A HEALTHIER, BRIGHTER WORLD.

Applying the Concepts: Kidney, Cryopreservation, and Plants

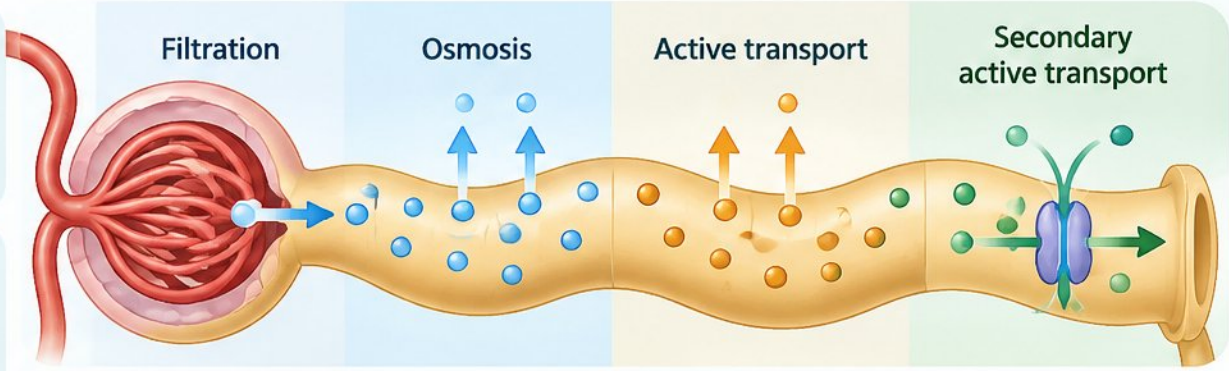
Nephron: filtration, osmosis, active and secondary active transport together

PCT: ~67% of water follows Na^+ osmotically; glucose by Na^+ symport

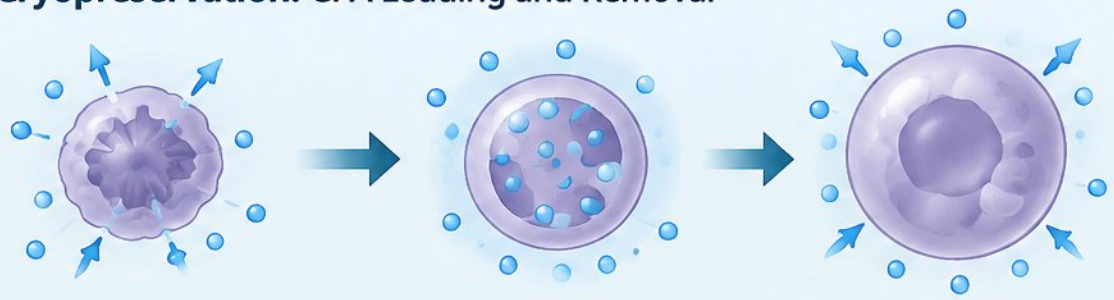
Loop of Henle: descending limb water osmosis; ascending limb active salt transport

Cryopreservation: permeating CPAs cause osmotic shrinkage, then swelling; stepwise loading limits injury

Plants: water uptake, stomatal control, osmotic adjustment under salinity stress



Cryopreservation: CPA Loading and Removal



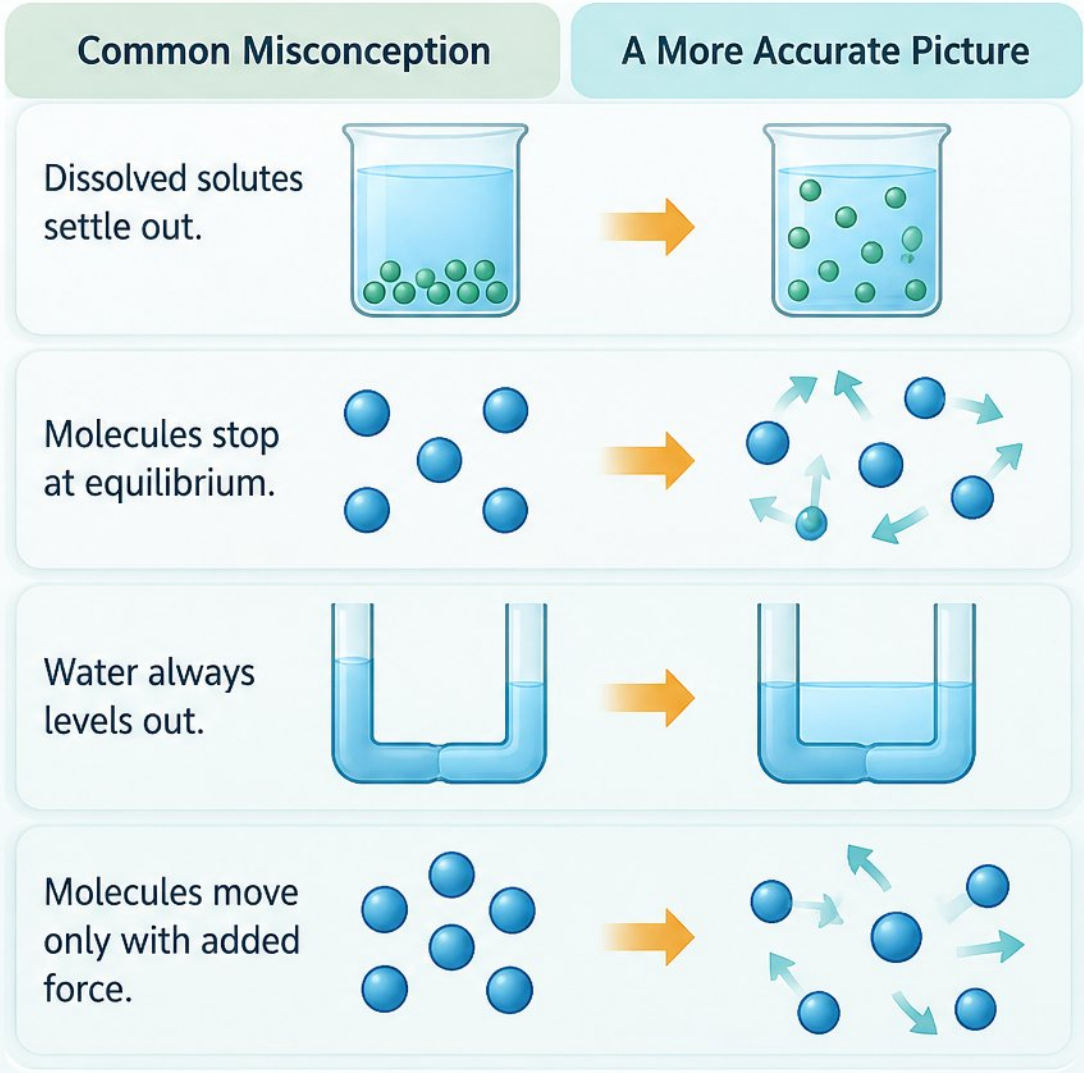
Plants: Water Movement and Stress Response



Decision flow: passive, facilitated, active, or bulk transport?

Diagnosing and Correcting Misconceptions

- Ask three questions: What is moving? Why does it move? Is energy needed?
- Common errors: dissolved solutes settle out; molecules stop at equilibrium
- Also frequent: water always levels out; molecules move only with added force
- Scaffold with gradient as driving force, random motion, and dynamic equilibrium
- Probe with two-tier items and clicker questions; adjust depth by audience
- Check analogies: a 'crowded room' misses the thermodynamic driving force

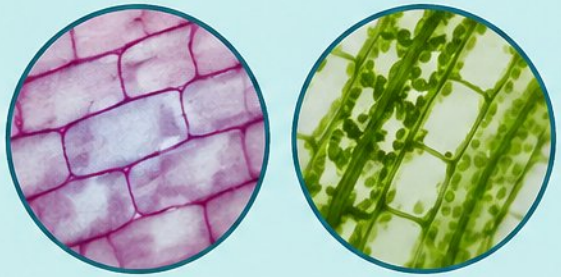


Teaching Strategies and Representational Sequences

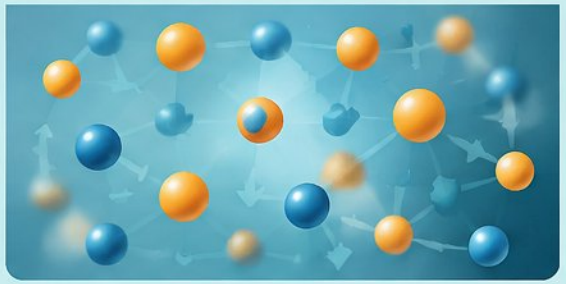
Macroscopic demonstration



Microscopy



Molecular simulation



Example models to choose from:



red onion



Elodea



decalcified eggs

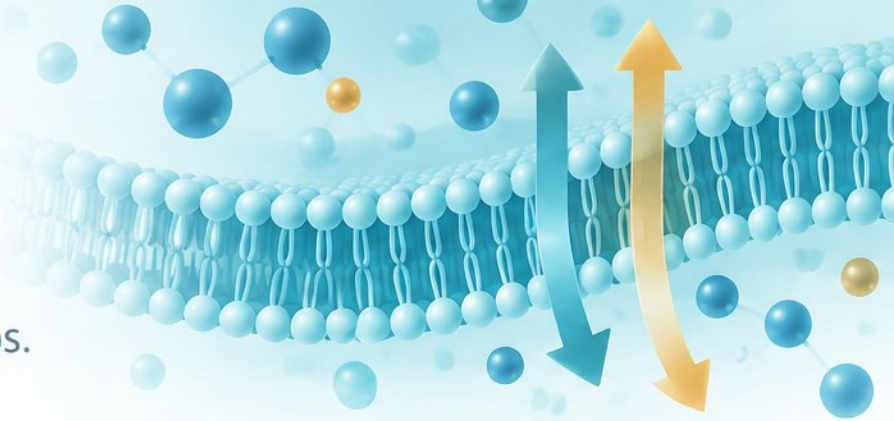


dialysis tubing

- Sequence representations: macroscopic demo → microscopy → molecular simulation
- Choose models by learning goal: red onion, *Elodea*, decalcified eggs, dialysis tubing
- Use inquiry simulations to make random motion and dynamic equilibrium visible
- Support conceptual change with concept mapping and conceptual change texts
- Plan for materials, safety, time, and *Elodea* invasive-species restrictions

Summary, Self-Check, and Next Steps

Consolidate what you've learned and plan your next steps.



Key Takeaways

- Driving forces, membrane selectivity, water potential, and tonicity vs. osmolarity

Self-Check

- Self-check: explain-your-reasoning items on gradients, tonicity, and active transport

Reflection Prompts

- Reflection prompts tailored for students, adult learners, and science teachers



Further Reading

- Further reading: OpenStax Biology, ODCA, DODT, and misconception research



Action Items

- Action items: plan a demonstration, revise an explanation, or design a two-tier item



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DEEPER UNDERSTANDING.

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