

Carriers and Channels

Plasma-membrane transport and cellular homeostasis

Robbins, Cotran & Kumar • Pathologic Basis of Disease • 11th ed.

Dr Abu Suraih Sakhri

MBBS, MD (Pathology)

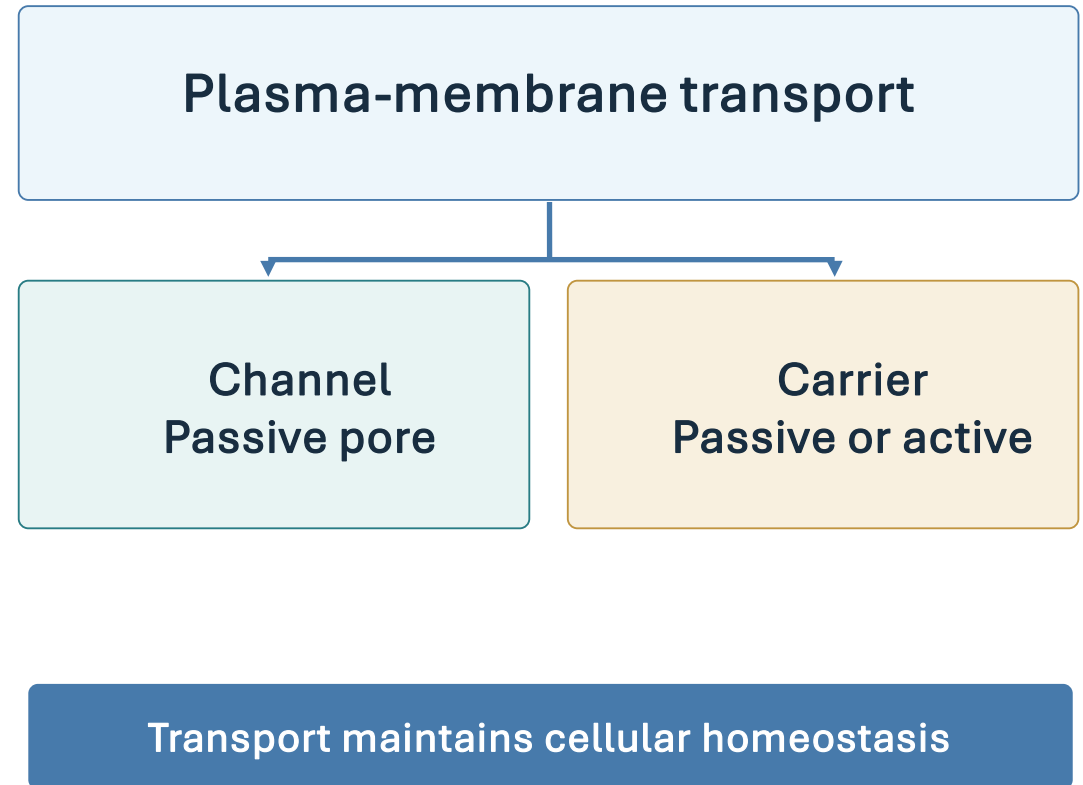
www.abusuraihsakhri.com

Learning outcomes

- Distinguish lipid diffusion, channels, and carriers.
- Explain passive versus active transport.
- Trace the Na^+ gradient to nutrient absorption.
- Relate transport failure to cell swelling and injury.
- Recognize transport-dependent drug resistance.

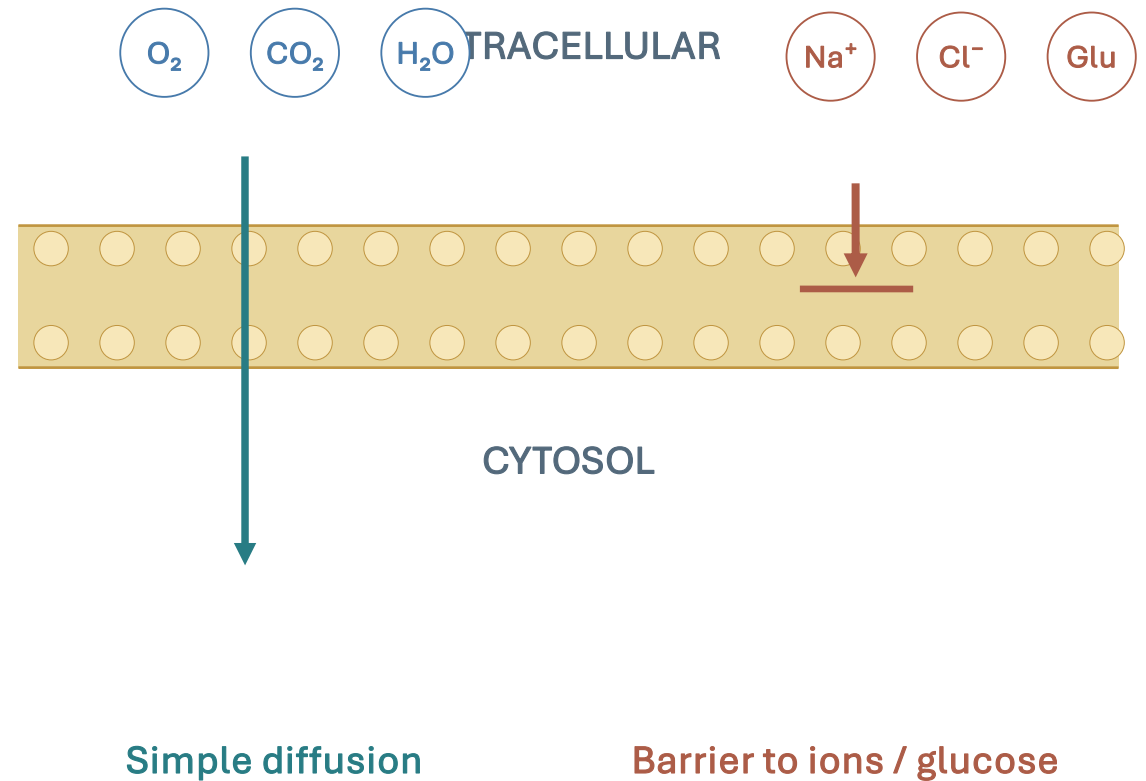
Transport is essential for cell function

- Cells must import nutrients and required ions.
- Waste products must leave the cell.
- Transport helps maintain ionic and osmotic conditions.
- Membranes also regulate transport into organelles.



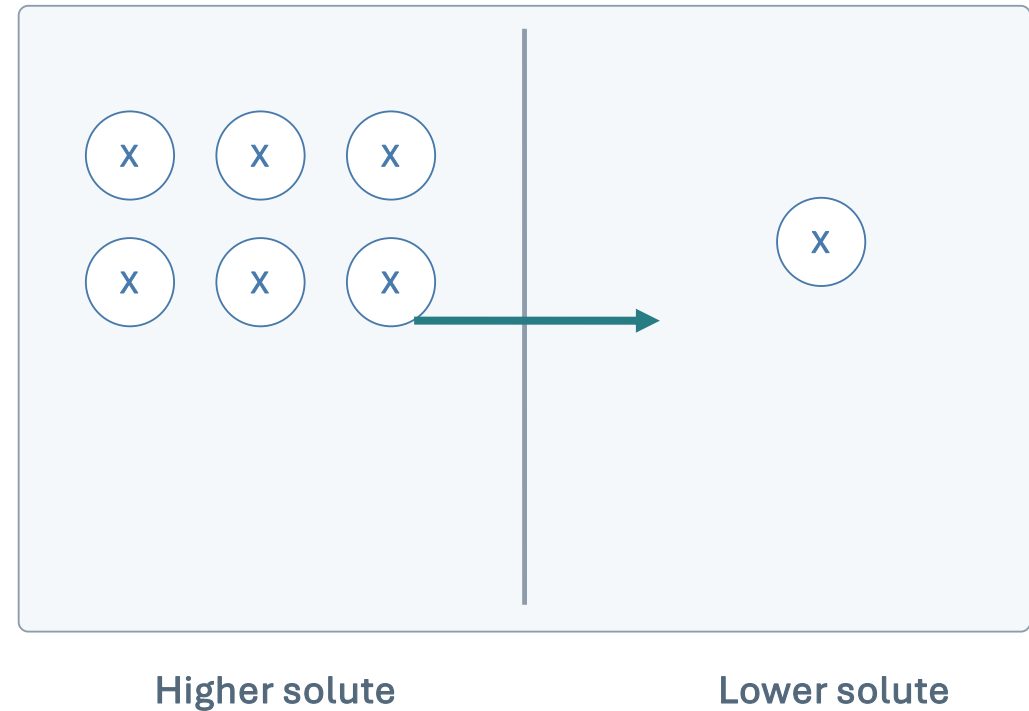
The lipid bilayer is a selective barrier

- Small nonpolar molecules pass readily.
- Glucose and charged ions are effectively excluded from free passage.
- Specialized proteins provide selective routes across membranes.



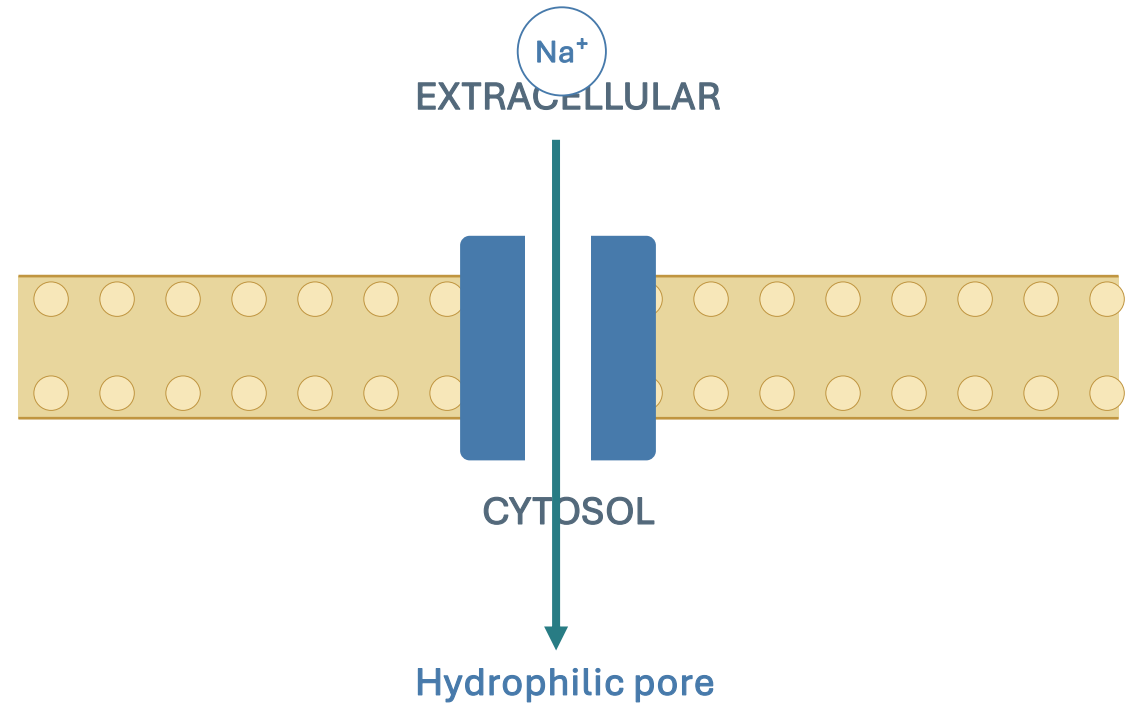
Simple diffusion does not use transport proteins

- O_2 and CO_2 readily dissolve in the lipid bilayer.
- Hydrophobic compounds may diffuse through the membrane.
- Transport follows a favorable gradient.



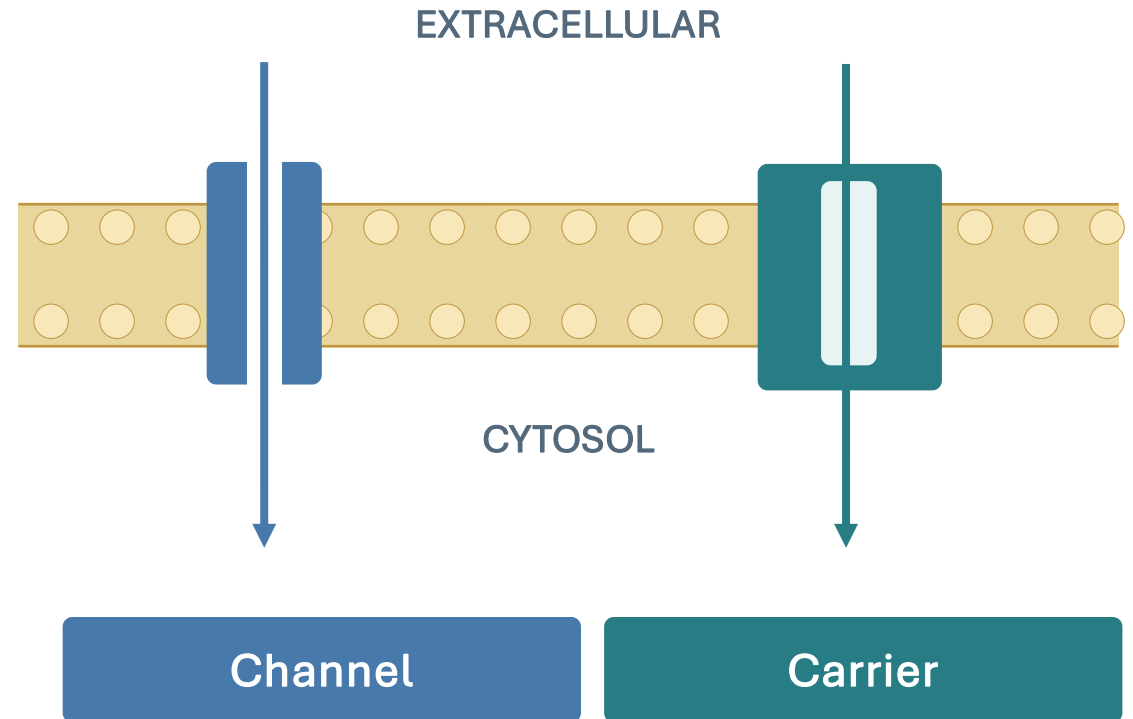
Water has two routes across membranes

- Water can cross lipid bilayers at a low rate.
- Aquaporins provide water-permeable channels.
- Transport remains passive, directed by solute distribution.



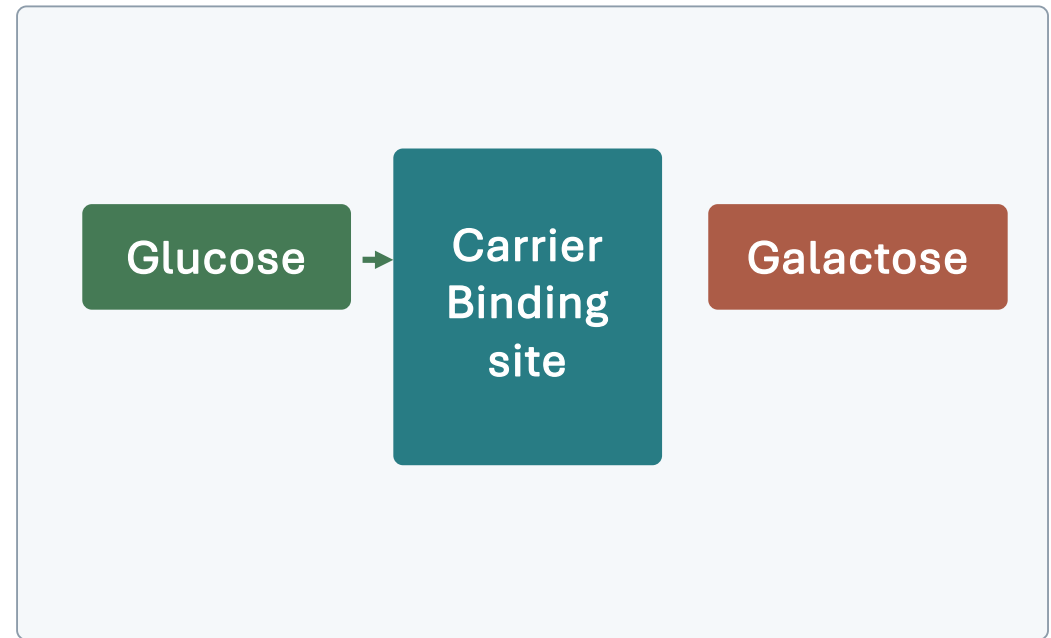
Channels and carriers move small solutes

- Channels provide a hydrophilic route.
- Carriers bind solutes and change conformation.
- Both enable selective movement otherwise restricted by the bilayer.



Transporters are selective

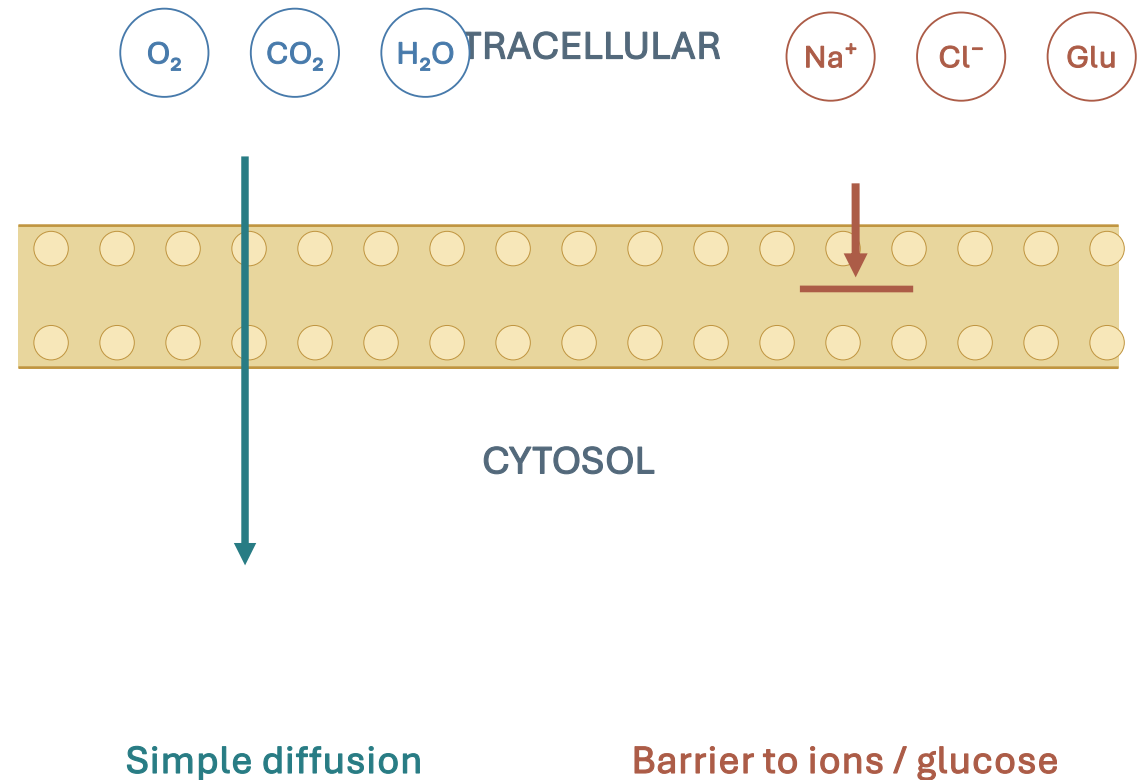
- Specificity can distinguish closely related solutes.
- A transporter may recognize glucose but not galactose.
- Selective transport prevents indiscriminate solute passage.



Selectivity differs among transporters

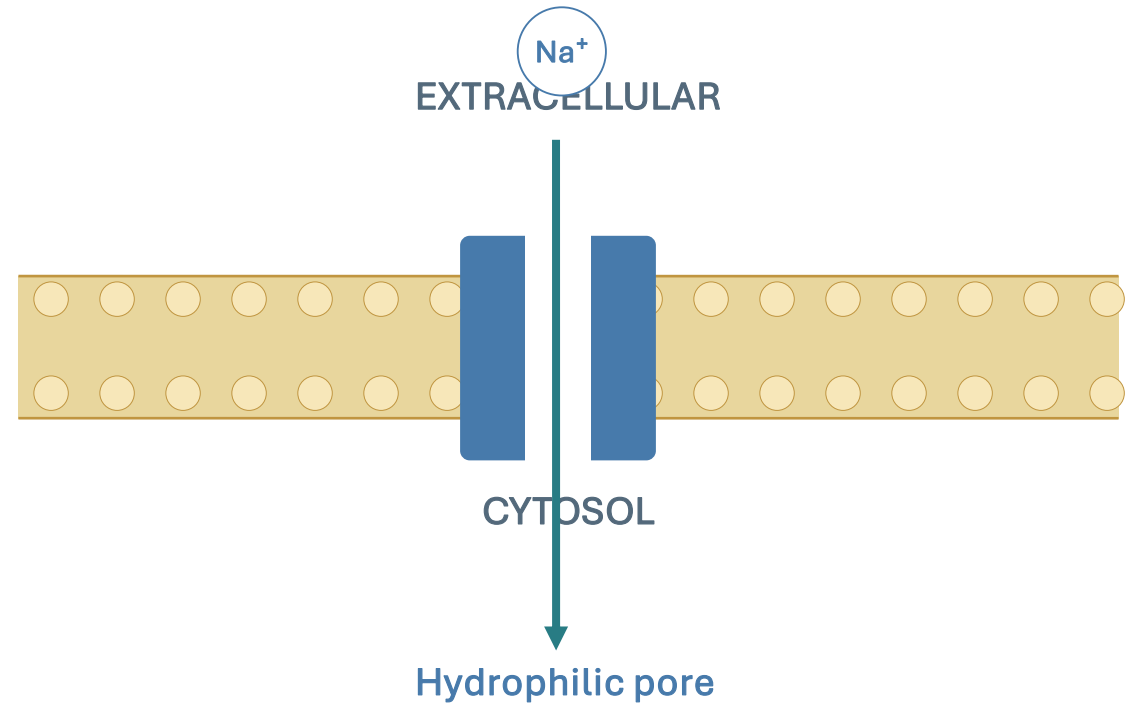
Selectivity is not the same as permeability

- The lipid bilayer limits entry of many polar species.
- A transporter provides a route for a defined substrate.
- Transport depends on the presence and properties of that protein.



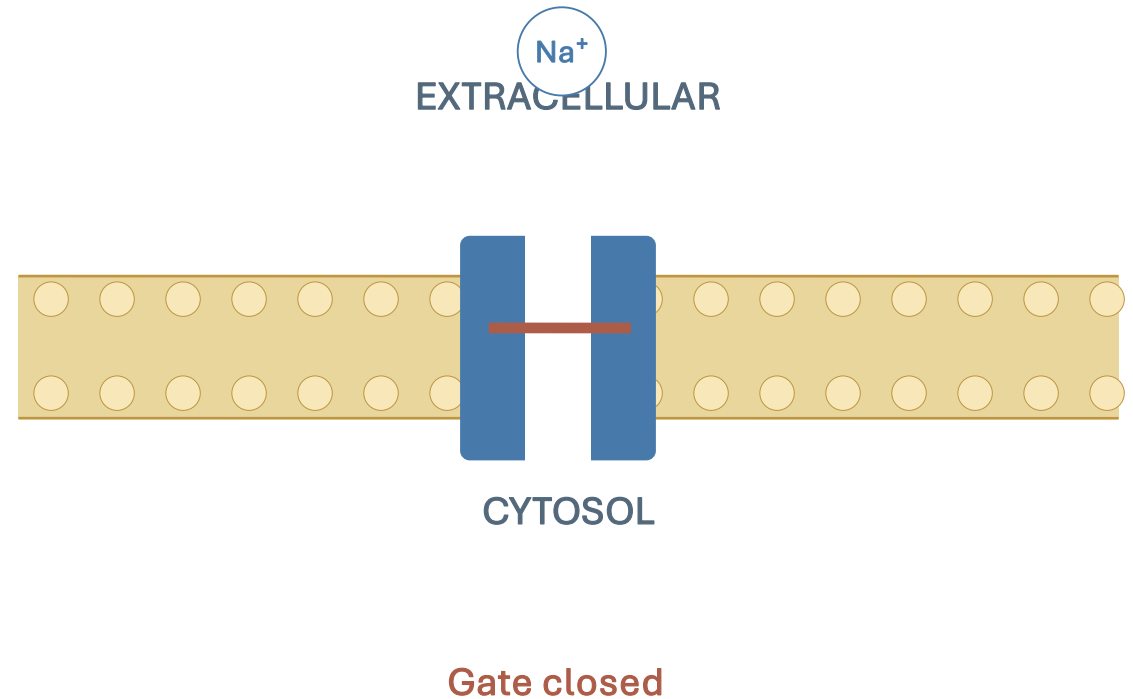
Channels form hydrophilic pores

- An open channel creates a water-compatible pathway.
- Solutes cross without the carrier-binding cycle.
- Movement is usually restricted by size and charge.



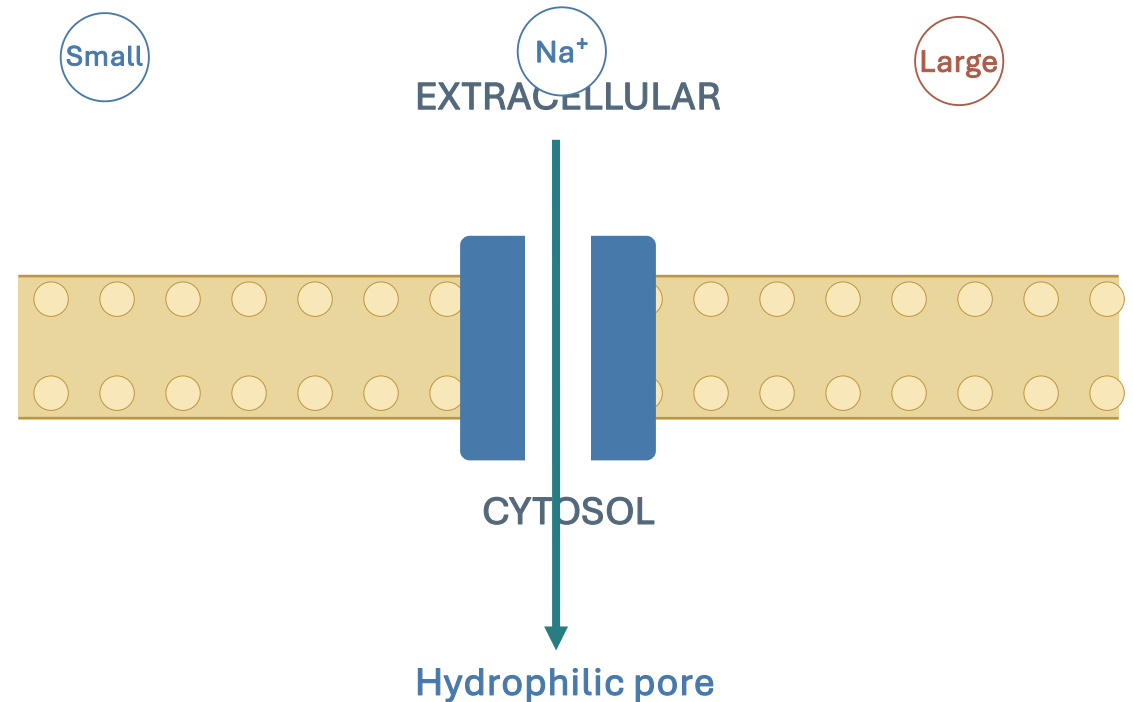
Opening is required for channel conductance

- A pore can conduct when it is open.
- A closed channel does not provide the same continuous path.
- The source defines channels by their open-pore function.



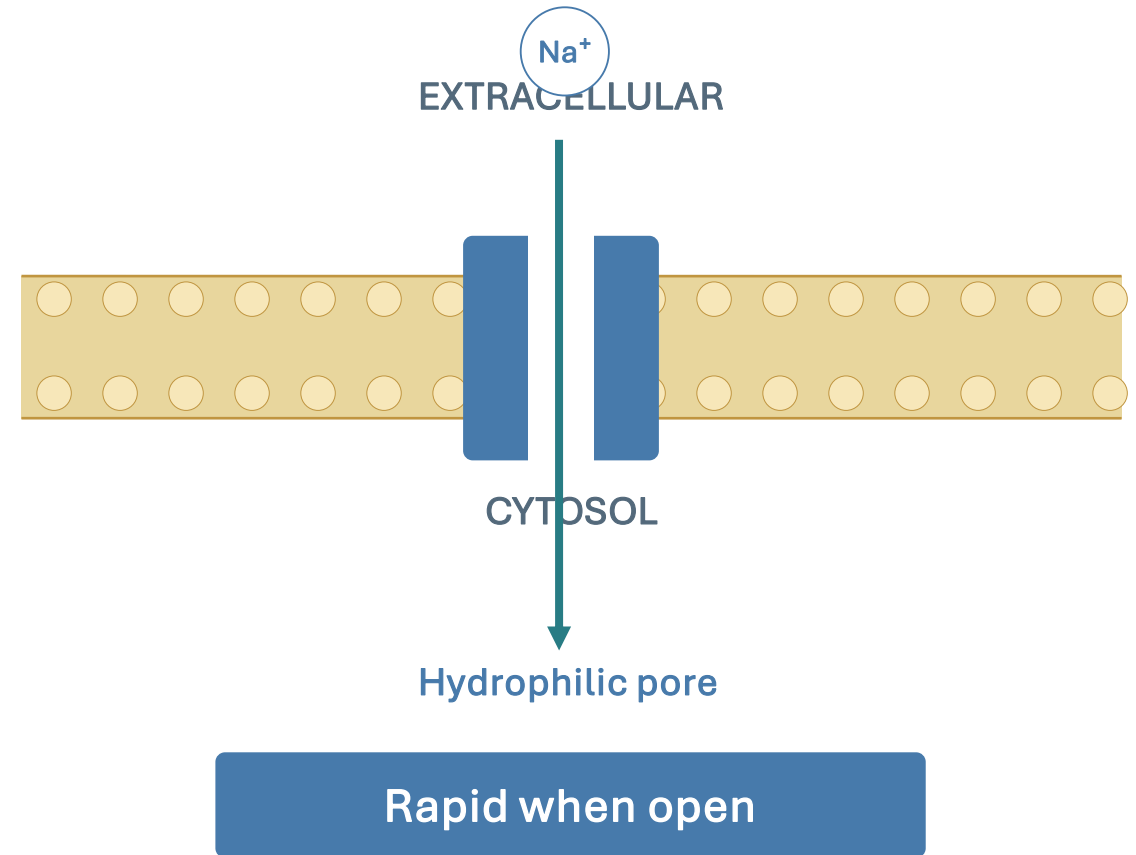
Channels distinguish ions by properties

- Pore dimensions limit which species can pass.
- Charge helps determine permissibility.
- A channel is not a nonspecific hole through the bilayer.



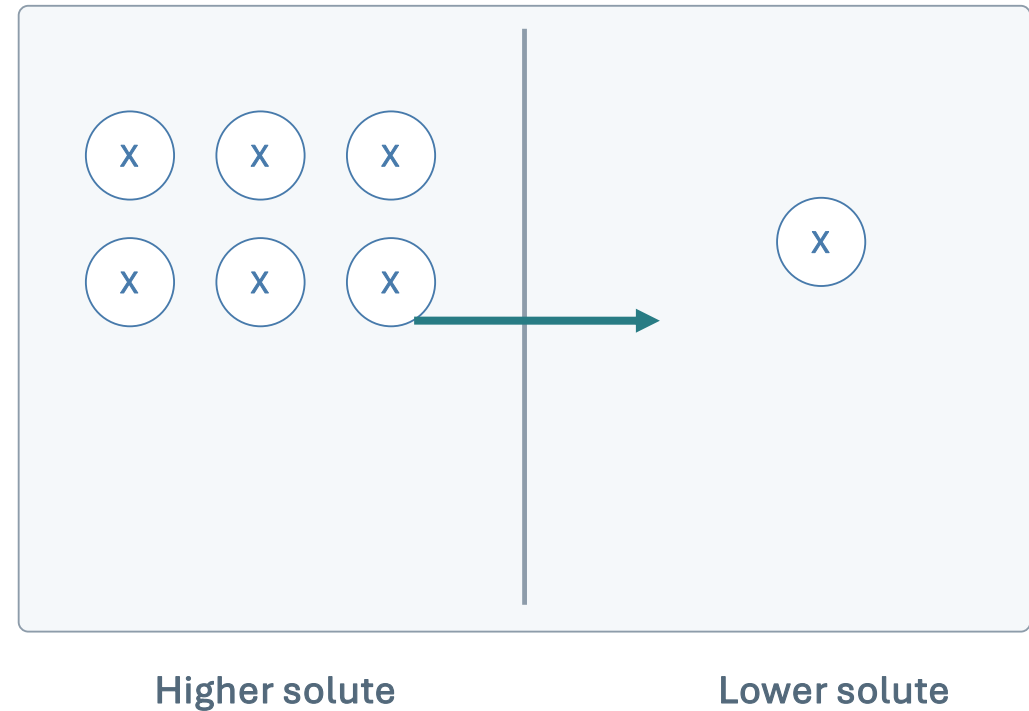
Open channels can move solute rapidly

- Hydrophilic pores allow rapid passage.
- Movement is facilitated along a favorable gradient.
- Channel transport does not drive solute uphill.



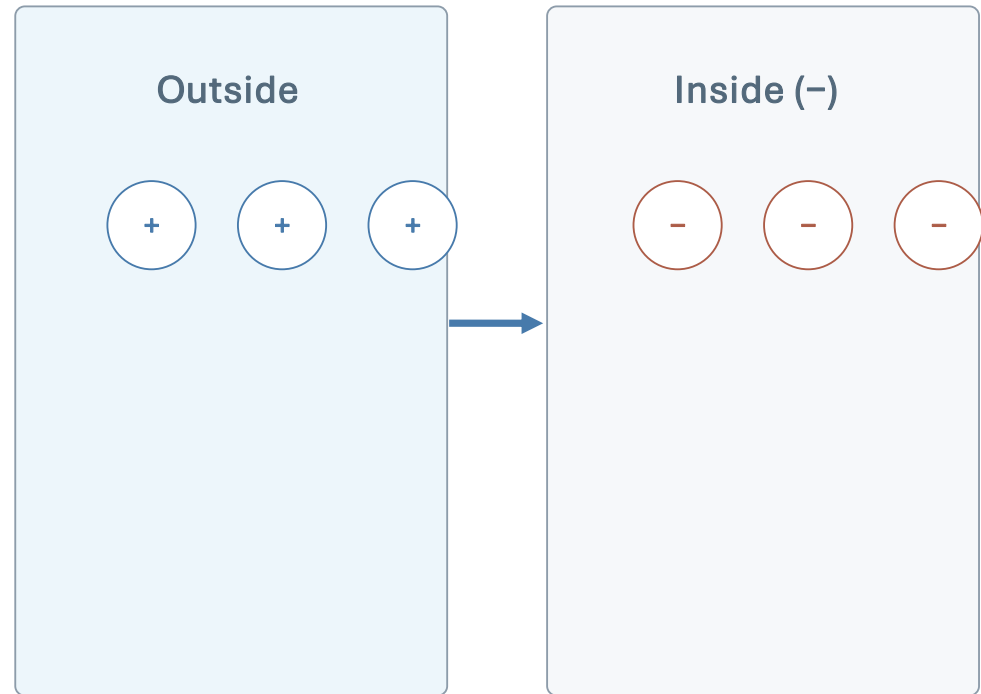
Concentration gradients drive passive movement

- A difference in concentration supplies a driving force.
- Net movement tends from higher to lower solute concentration.
- No direct ATP expenditure is required for this process.



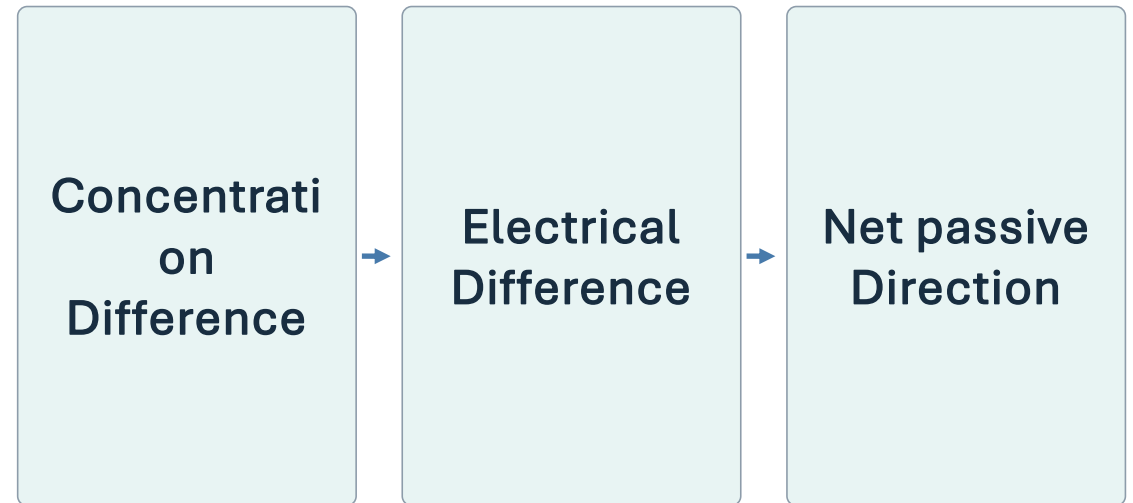
Cell membranes also have electrical gradients

- Virtually all plasma membranes have a potential difference.
- The inside is typically negative relative to the outside.
- Electrical and concentration gradients both influence ions.



Electrochemical driving force combines two effects

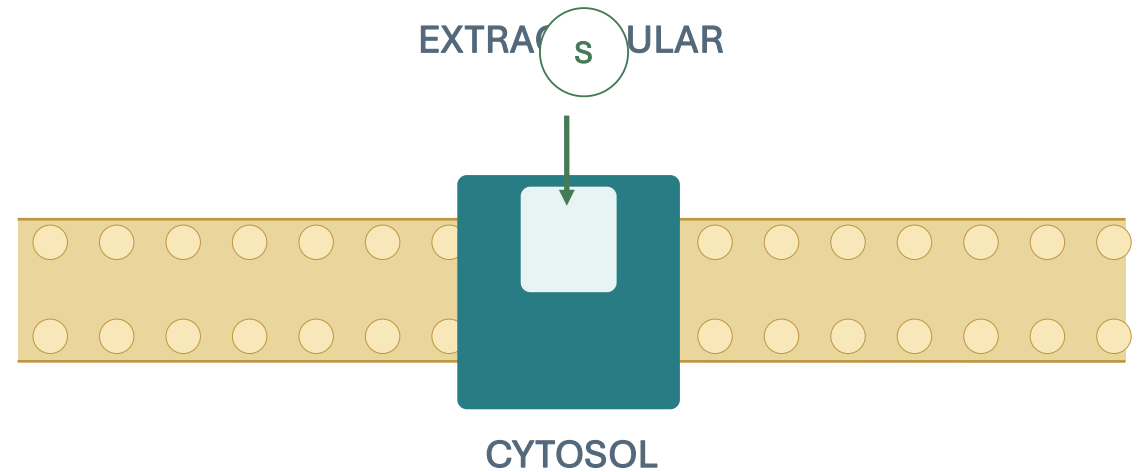
- Concentration differences favor redistribution of solute.
- Electrical potential influences charged solutes.
- Passive ion movement reflects the combined influence.



Direction reflects both influences

Carriers bind specific solutes

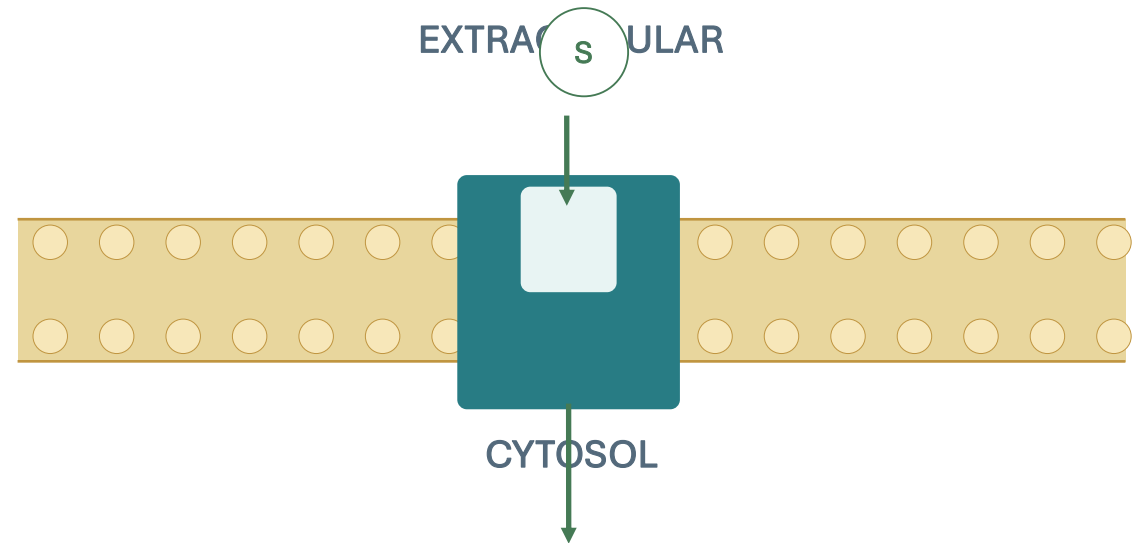
- A substrate binds to the transporter.
- Binding precedes transmembrane transfer.
- The binding site helps determine transporter specificity.



Specific solute-binding site

Carrier movement requires conformational change

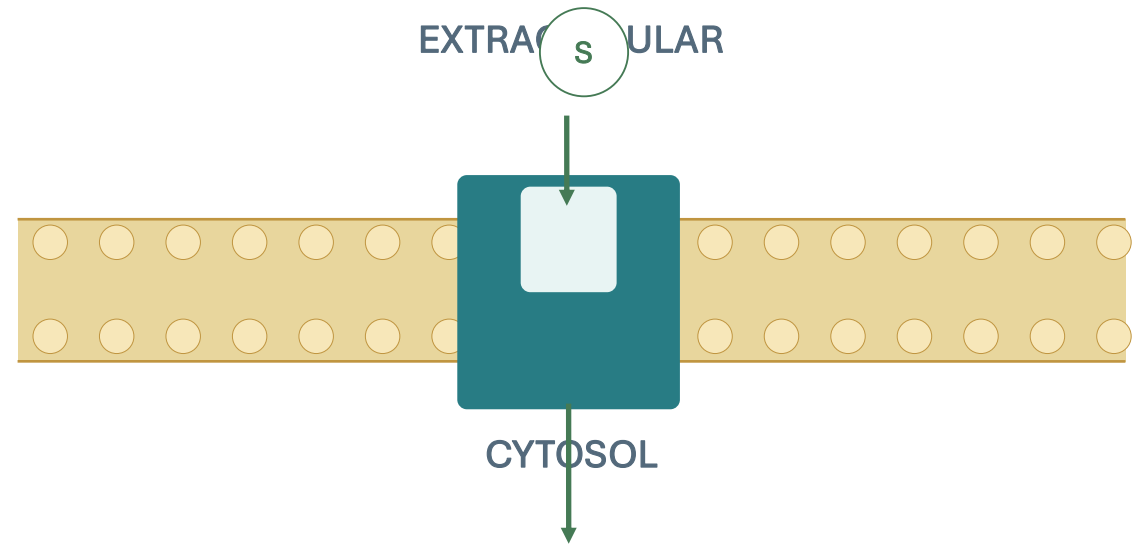
- The protein changes its conformation.
- The substrate is transferred across the bilayer.
- This is distinct from passage through an open channel.



Bind → change shape → release

Carrier transport is relatively slow

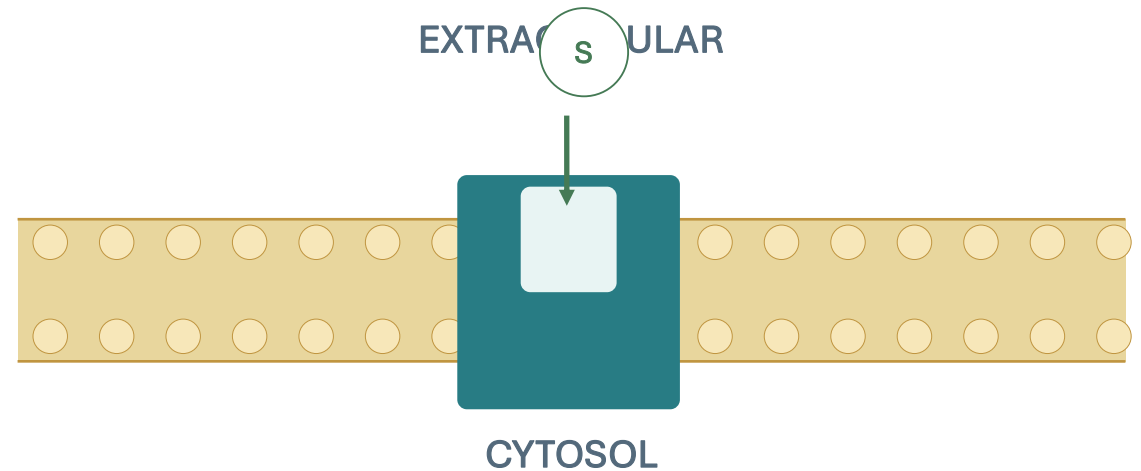
- The carrier must complete a conformational cycle.
- Channels permit rapid transfer through an open pore.
- The mechanistic distinction is central to transport classification.



Bind → change shape → release

Carriers may mediate passive transport

- A carrier can move solute along a favorable gradient.
- Transport need not consume ATP directly.
- Classification depends on direction and energy coupling.



Specific solute-binding site

Channel versus carrier

CHANNEL

- Hydrophilic pore
- Fast when open
- Size/charge selectivity
- Passive solute movement

CARRIER

- Binds specific substrate
- Changes conformation
- Relatively slower
- Passive or active transfer

Active transport against a gradient requires carriers.

Mechanism check: Identify the route

Which transport mechanism can move a solute against its concentration gradient?

A. An open channel alone

B. A suitably energized carrier

C. Simple diffusion through lipid

D. An unassisted aqueous pore

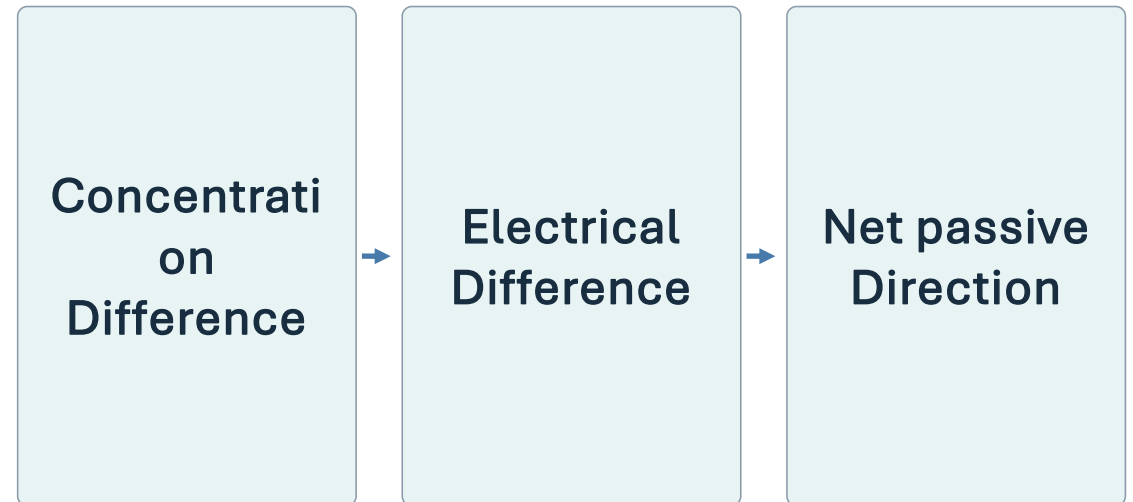
Carrier transport can be active

B. A suitably energized carrier

- Channels mediate passage along favorable gradients.
- Active movement against a gradient requires an energy source.
- Energy may come from ATP hydrolysis or a coupled ion gradient.

Passive transport follows driving forces

- The concentration gradient can power movement.
- Electrical potential also influences ion transport.
- Passive transport does not itself drive uphill movement.



Direction reflects both influences

Active transport moves solute uphill

- The transported solute may move against its concentration gradient.
- A carrier—not a channel—performs this task.
- The process is energized by ATP or a coupled gradient.

ATP hydrolysis

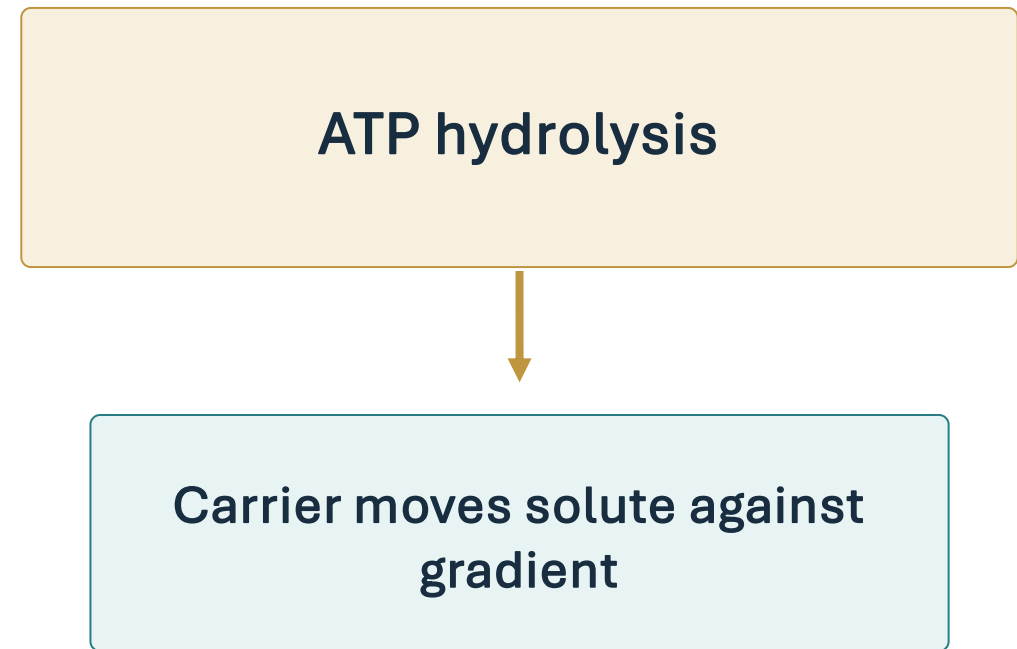
```
graph TD; A[ATP hydrolysis] --> B[Carrier moves solute against gradient]
```

The diagram consists of two rectangular boxes connected by a downward-pointing arrow. The top box is light orange and contains the text 'ATP hydrolysis'. The bottom box is light blue and contains the text 'Carrier moves solute against gradient'. The arrow is orange and points from the bottom of the top box to the top of the bottom box.

**Carrier moves solute against
gradient**

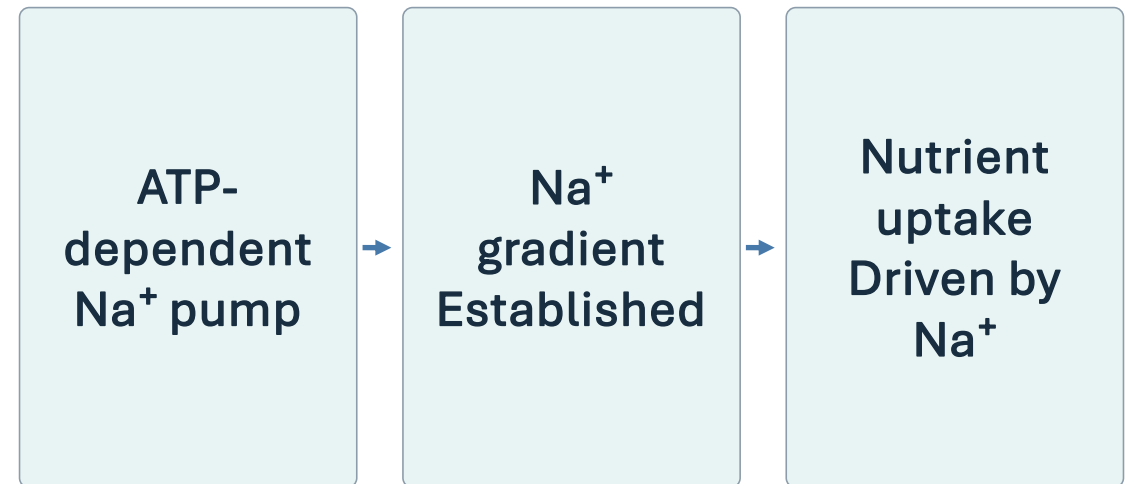
Direct ATP use supports active carriers

- Certain transporters are ATPases.
- ATP hydrolysis provides energy for unfavorable solute movement.
- The transport protein couples an energy reaction to transfer.



Ion gradients can indirectly power uptake

- A pre-existing Na^+ gradient can drive nutrient absorption.
- The nutrient may move against its own concentration gradient.
- ATP is not used directly by that apical cotransport event.



Indirect ATP dependence

Two routes to active transport

ATP-DRIVEN

- ATP hydrolysis at the transporter
- Energy expenditure is direct
- Example: Na⁺,K⁺-ATPase

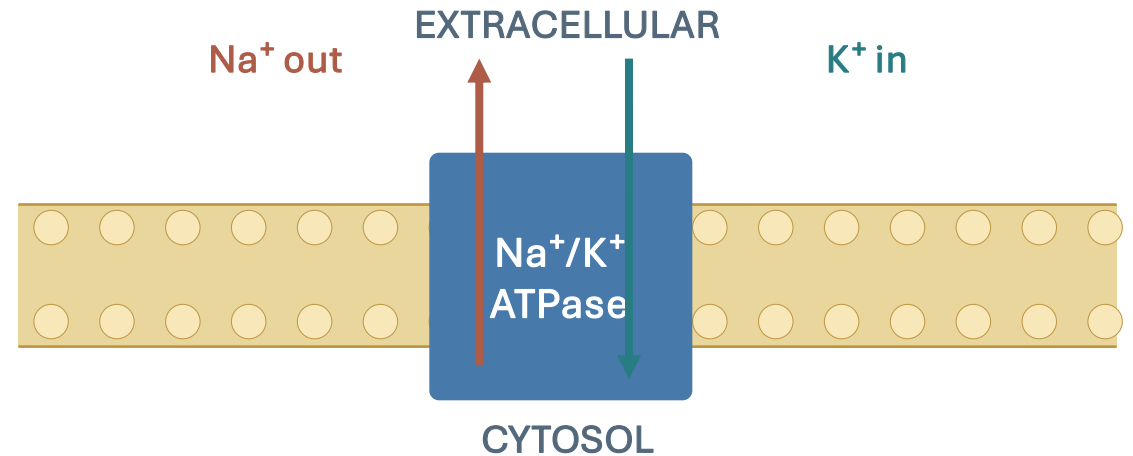
ION-GRADIENT-COUPLED

- Uses an established ion gradient
- ATP dependence is indirect
- Example: Na⁺-linked apical nutrient absorption

Both require a carrier; Neither is channel-mediated uphill pumping.

Na^+, K^+ -ATPase generates a Na^+ gradient

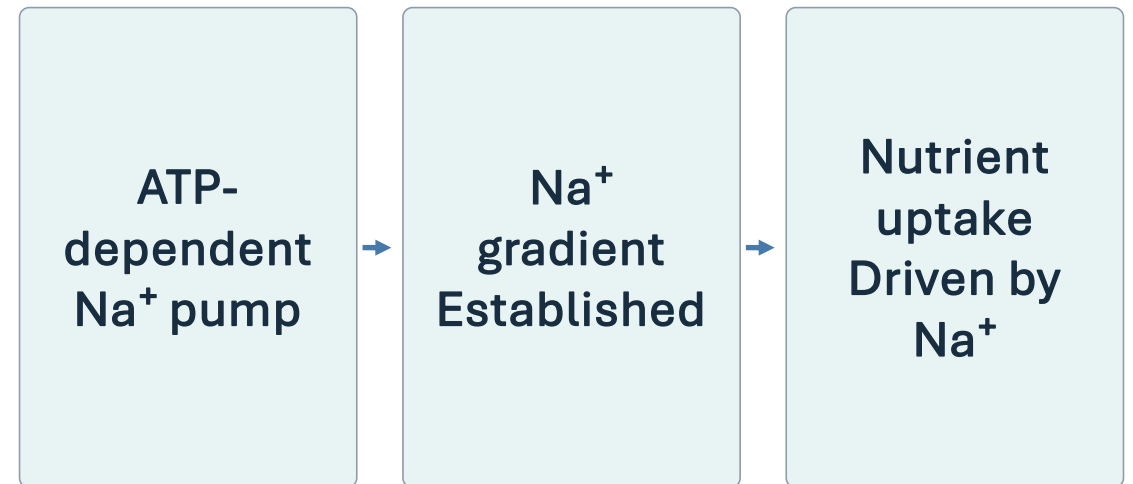
- The membrane ATPase exchanges inorganic ions.
- ATP use helps keep intracellular Na^+ low.
- That gradient becomes usable energy for other carriers.



ATP-driven ion exchange

The Na^+ gradient is a cellular energy resource

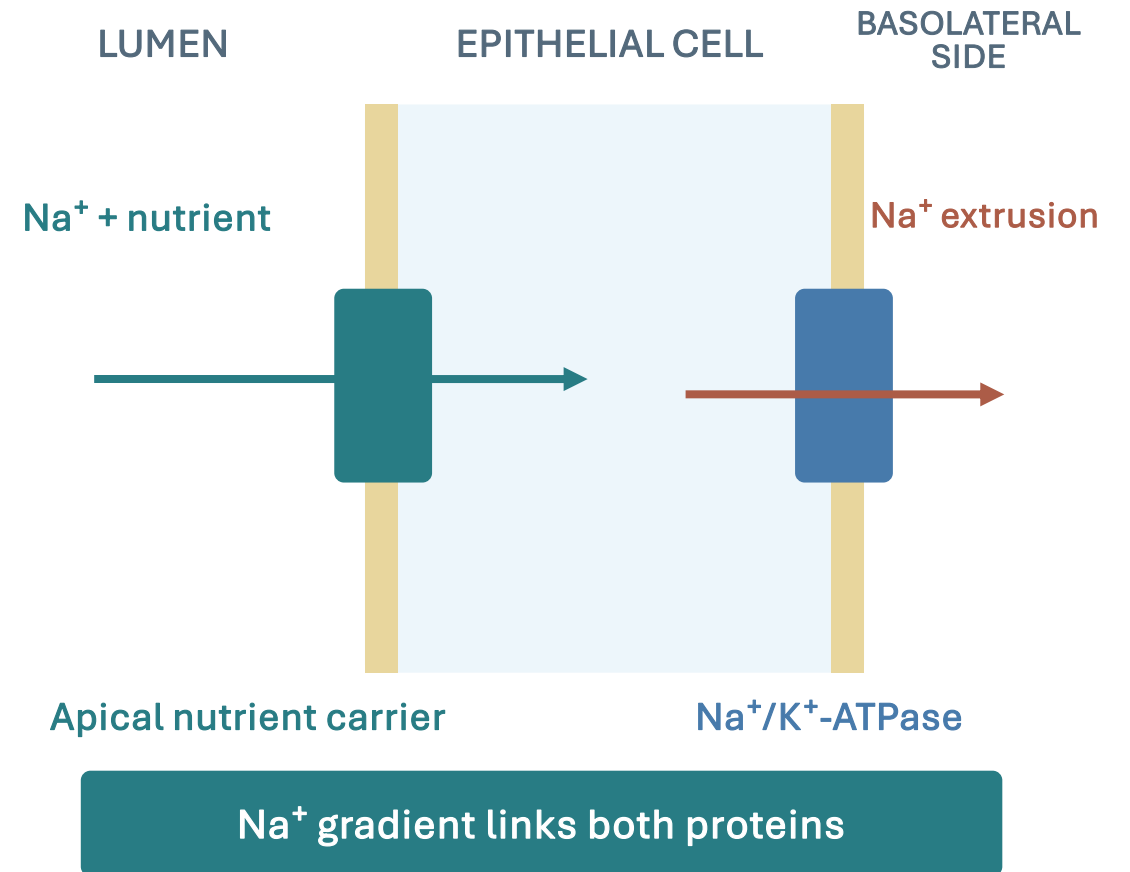
- Na^+ tends to enter along its gradient.
- Coupled carriers exploit that tendency.
- Nutrient uptake may proceed despite an opposing nutrient gradient.



Indirect ATP dependence

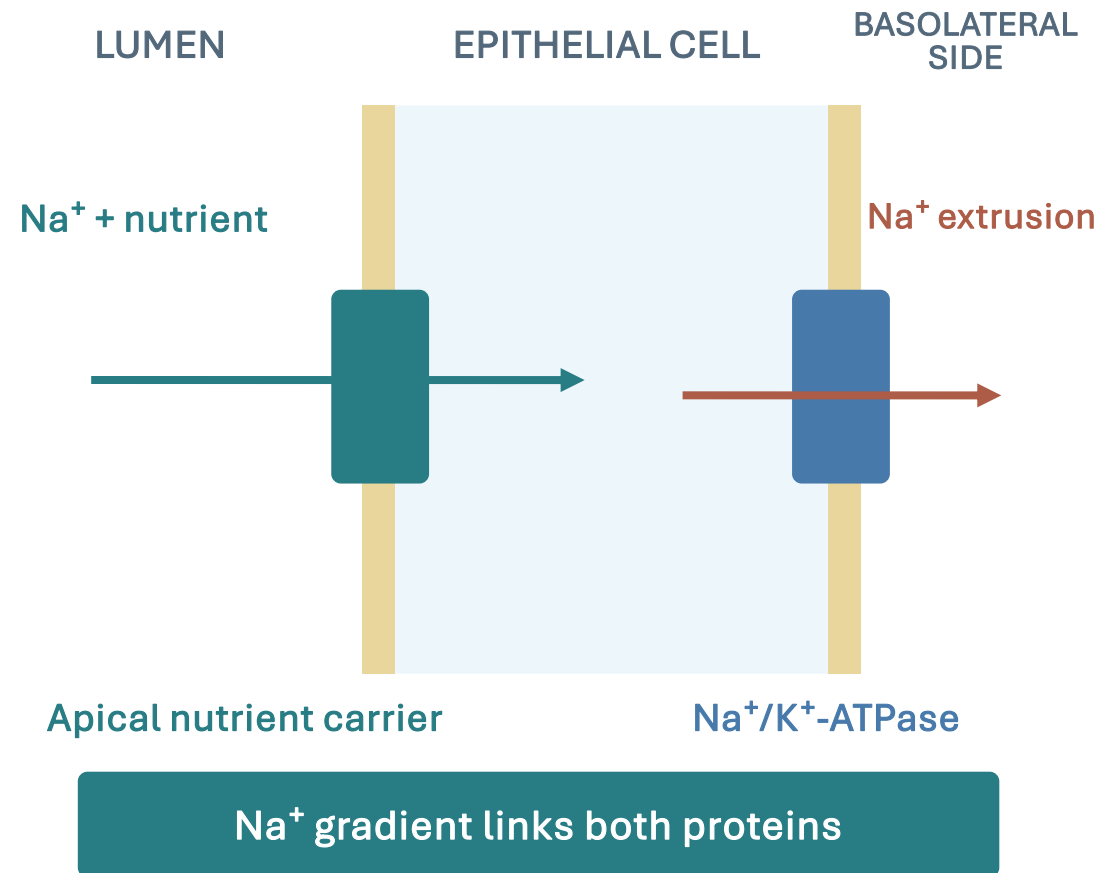
Apical nutrient carriers use Na^+ coupling

- An apical transporter brings nutrient into the cell.
- Na^+ entry provides the favorable driving step.
- Na^+, K^+ -ATPase sustains the requisite gradient.



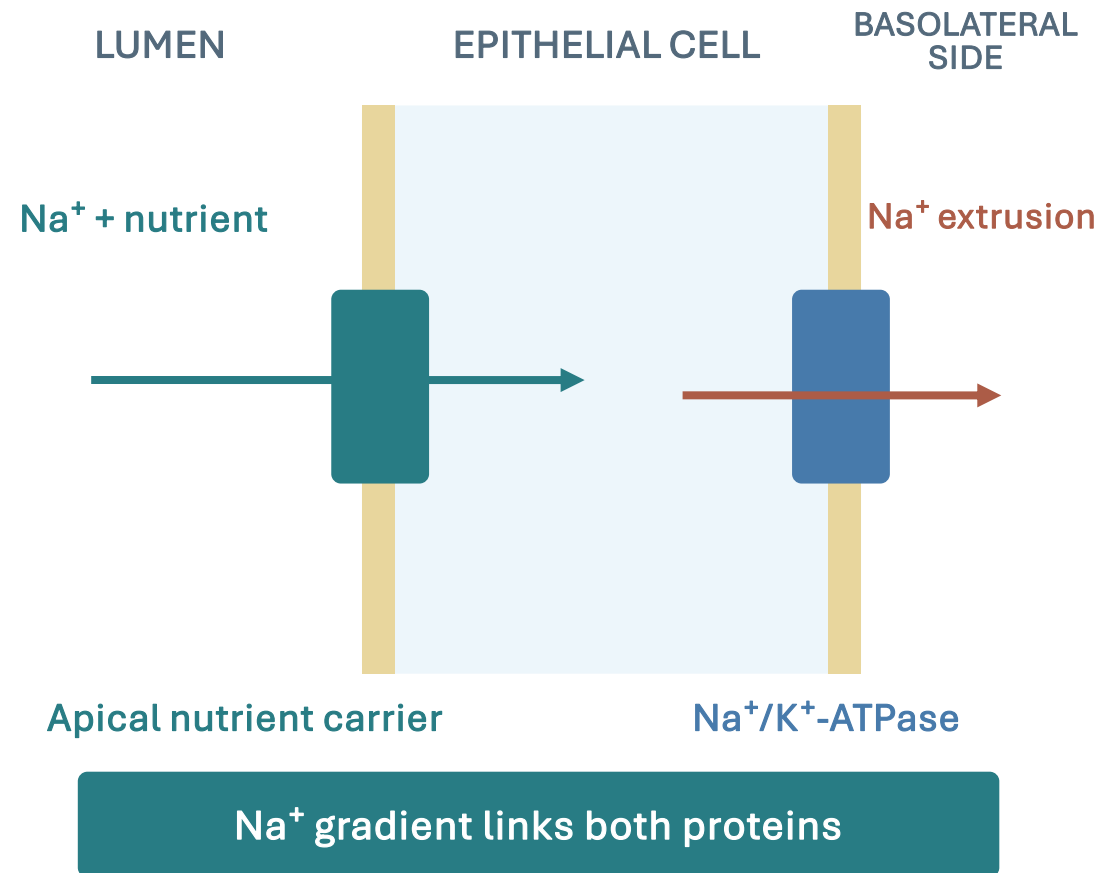
Intestinal epithelia use secondary active uptake

- Apical nutrient transport may be Na^+ -linked.
- Intracellular nutrient concentration need not be lower.
- The driving gradient is maintained by Na^+, K^+ -ATPase.



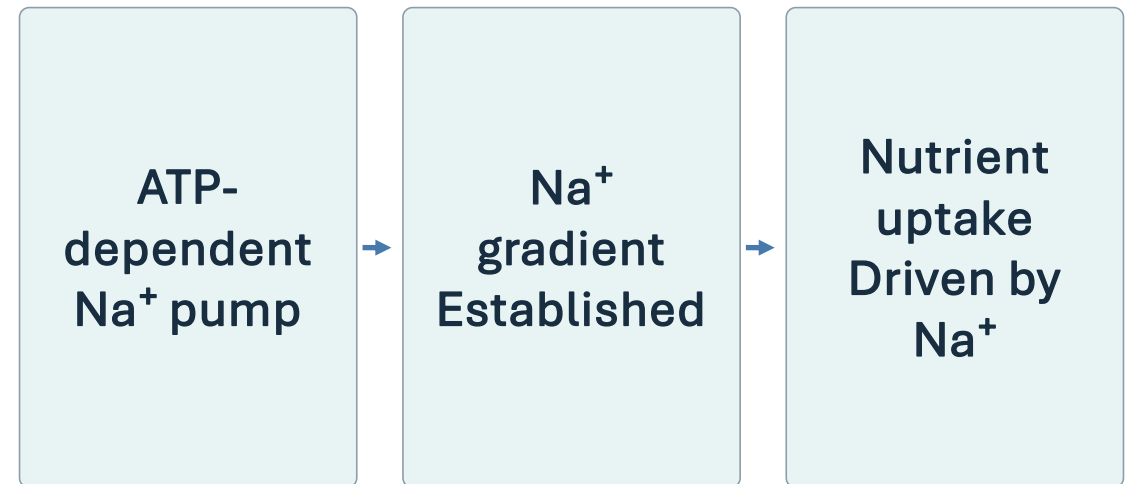
Renal tubules exploit the same principle

- Apical nutrient uptake can depend on Na^+ influx.
- Nutrient movement may oppose its own gradient.
- Failure of the Na^+ gradient compromises this transport logic.



Nutrient uptake can oppose its own gradient

- Favorable Na^+ entry is coupled to nutrient movement.
- The two solutes need not share the same concentration direction.
- This is why indirect energy coupling matters.



Indirect ATP dependence

Application: Coupled absorption

An epithelial cell accumulates a nutrient above its extracellular concentration. What permits continued apical uptake?

A. The lipid bilayer alone

B. A channel with no energy coupling

C. A carrier coupled to the Na^+ gradient

D. Water osmosis

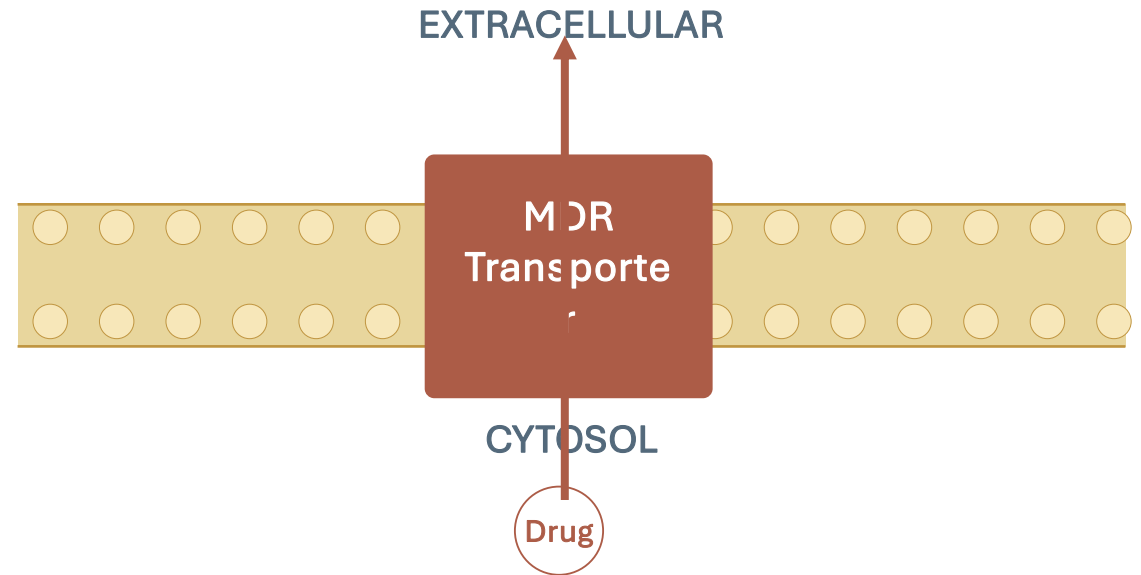
Na⁺ gradient supports apical nutrient uptake

C. A carrier coupled to the Na⁺ gradient

- The nutrient can move against its gradient.
- Na⁺ moves down a favorable gradient.
- The Na⁺ gradient ultimately depends on ATPase activity.

Multidrug-resistance proteins can be ATPases

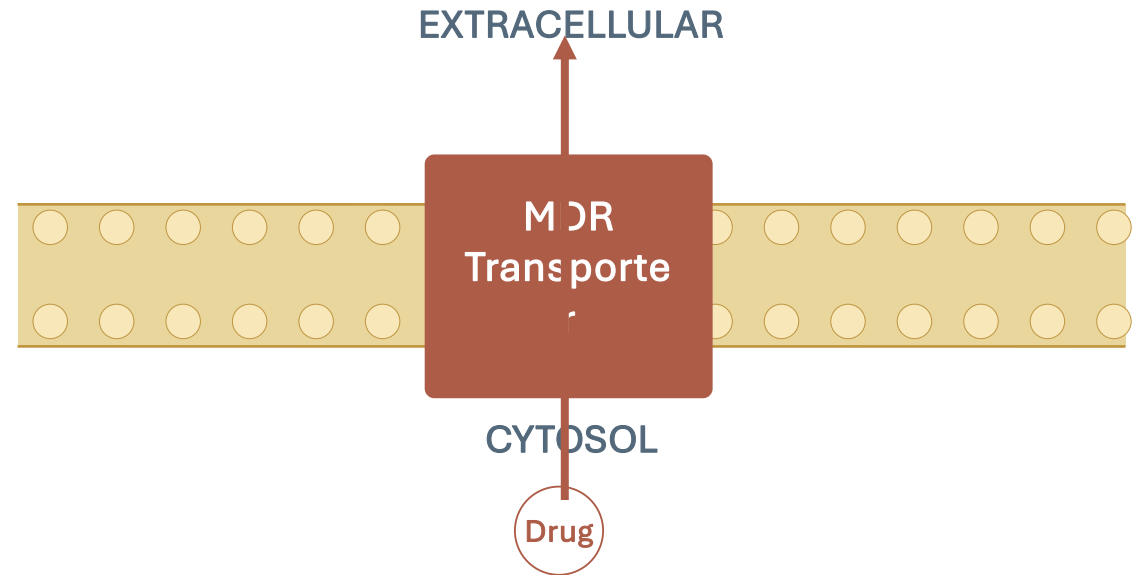
- Some transporter ATPases expel polar compounds.
- Chemotherapeutic drugs are among the possible substrates.
- Active export lowers cellular exposure to transported drugs.



Export of polar compounds

Drug efflux can undermine chemotherapy

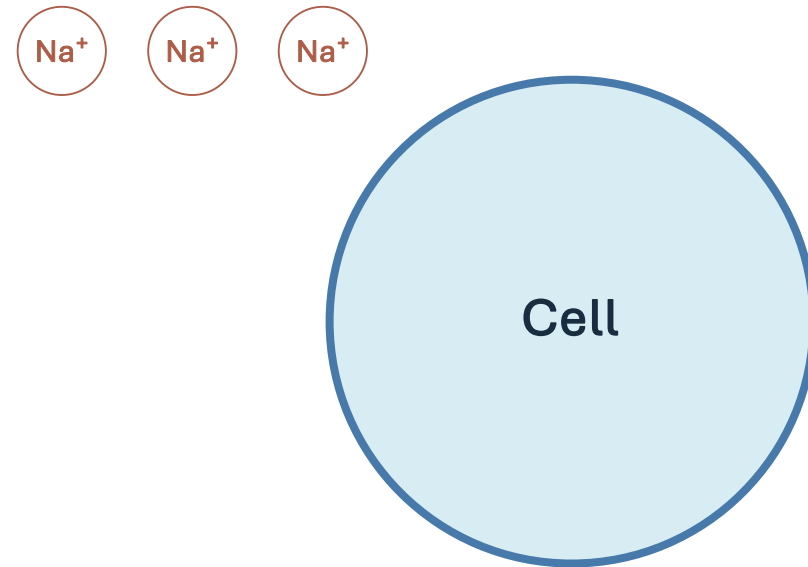
- An MDR protein pumps certain drugs out of cells.
- Tumor cells expressing the relevant transport mechanism may resist therapy.
- This is a transport-mediated form of treatment resistance.



Export of polar compounds

Water follows osmotic differences

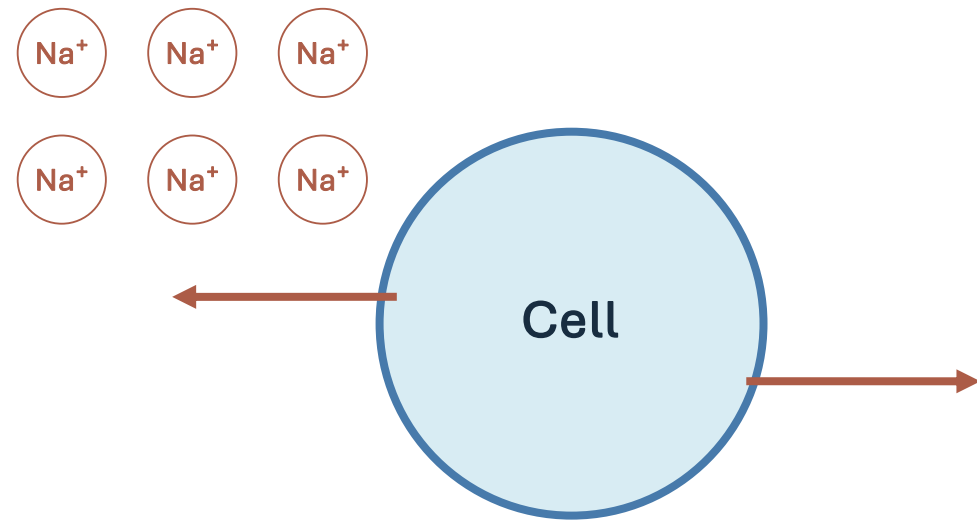
- Water movement is passive.
- Solute concentration directs net water movement.
- Tonicity therefore changes cell volume.



Water follows osmotic differences

Hypertonicity promotes cell shrinkage

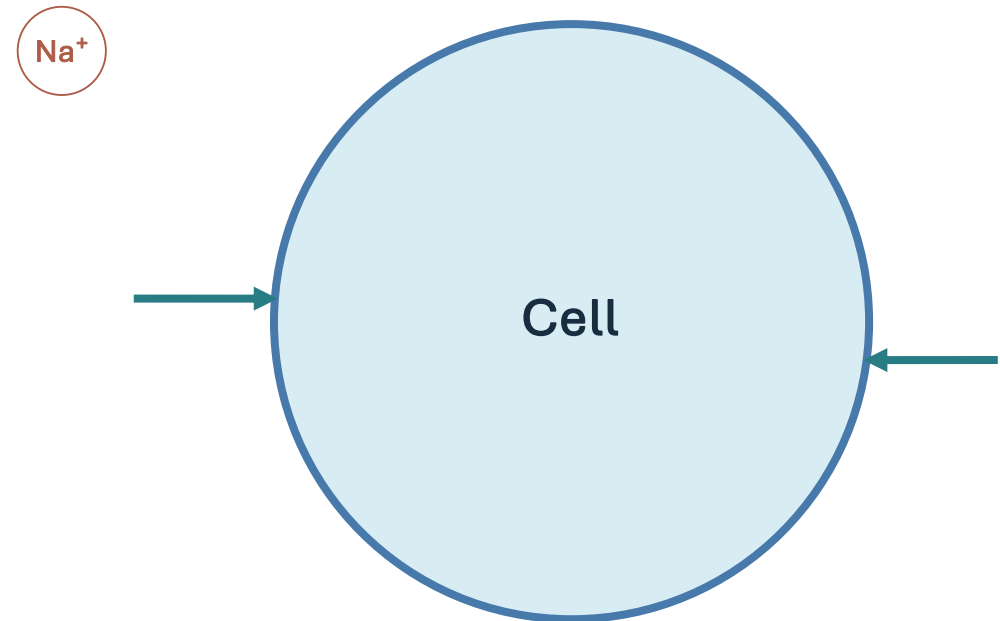
- Extracellular salt exceeds the relative intracellular level.
- Water leaves the cell.
- Net water loss reduces cellular volume.



Water exits → cell shrinks

Hypotonicity promotes cell swelling

- Extracellular solute is relatively dilute.
- Water enters the cell.
- Net water gain increases cellular volume.



Water enters → cell swells

Effect of external tonicity

HYPERTONIC ENVIRONMENT

- Relatively high extracellular solute
- Net water movement outward
- Cell shrinks

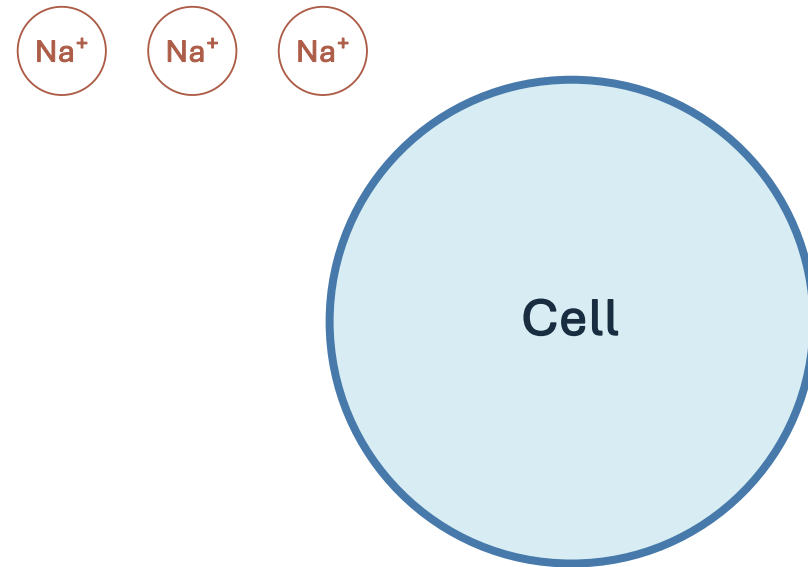
HYPOTONIC ENVIRONMENT

- Relatively low extracellular solute
- Net water movement inward
- Cell swells

Tonicity describes the direction of net water movement.

The cytoplasm contains an osmotic load

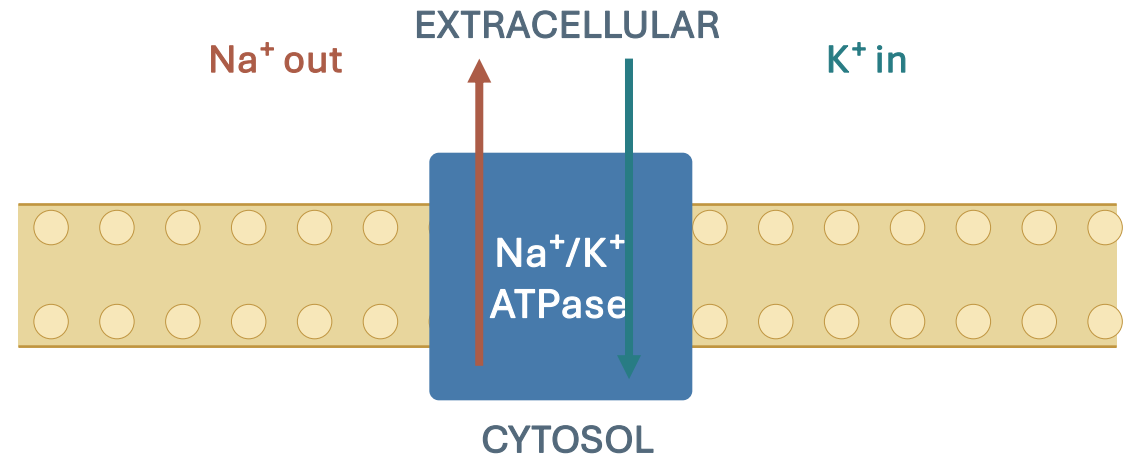
- Intracellular charged proteins attract counterions.
- Metabolites also contribute to intracellular osmolarity.
- Without compensation, water would accumulate.



Water follows osmotic differences

Na^+ extrusion protects against overhydration

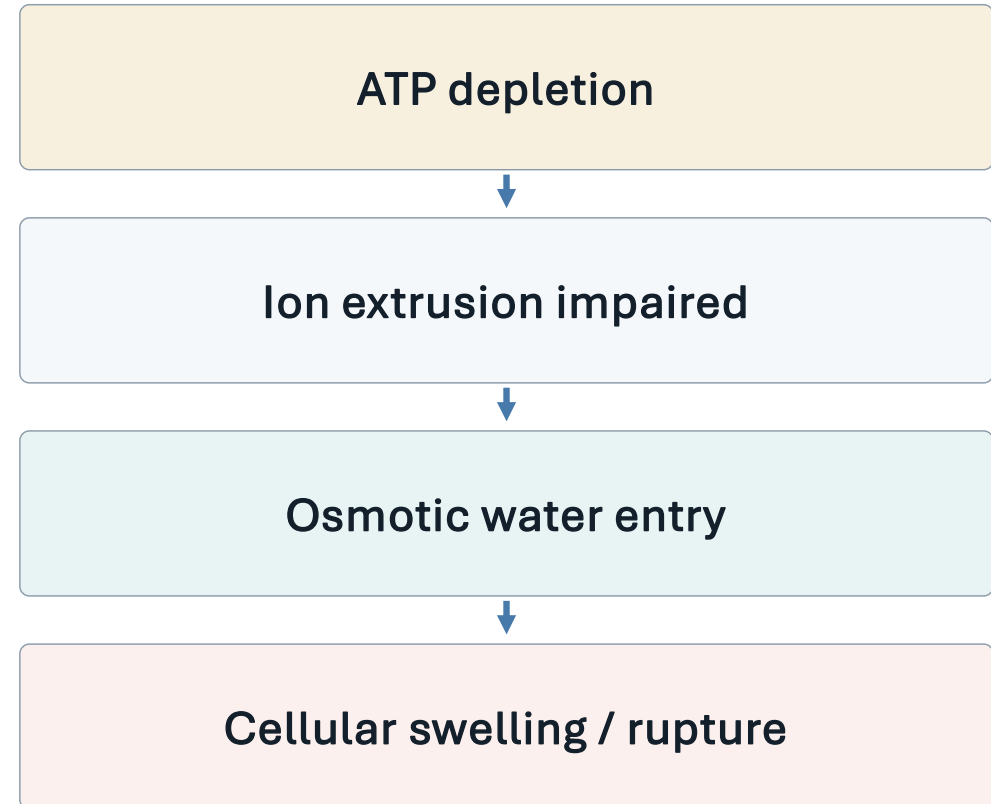
- Cells continuously expel small inorganic ions.
- Membrane ion-exchanging ATPase activity is important.
- Ion transport protects cell volume.



ATP-driven ion exchange

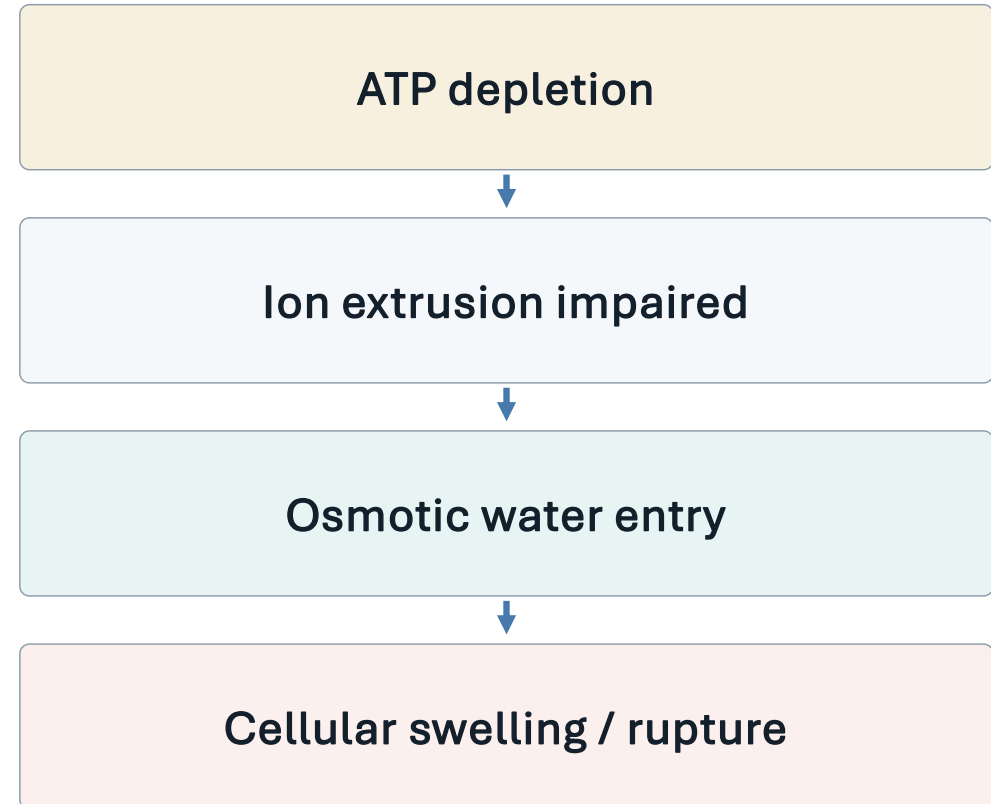
Energy depletion disables volume control

- Toxins or ischemia can impair cellular energy generation.
- Ion pumping can then fail.
- Osmotic imbalance produces swelling.



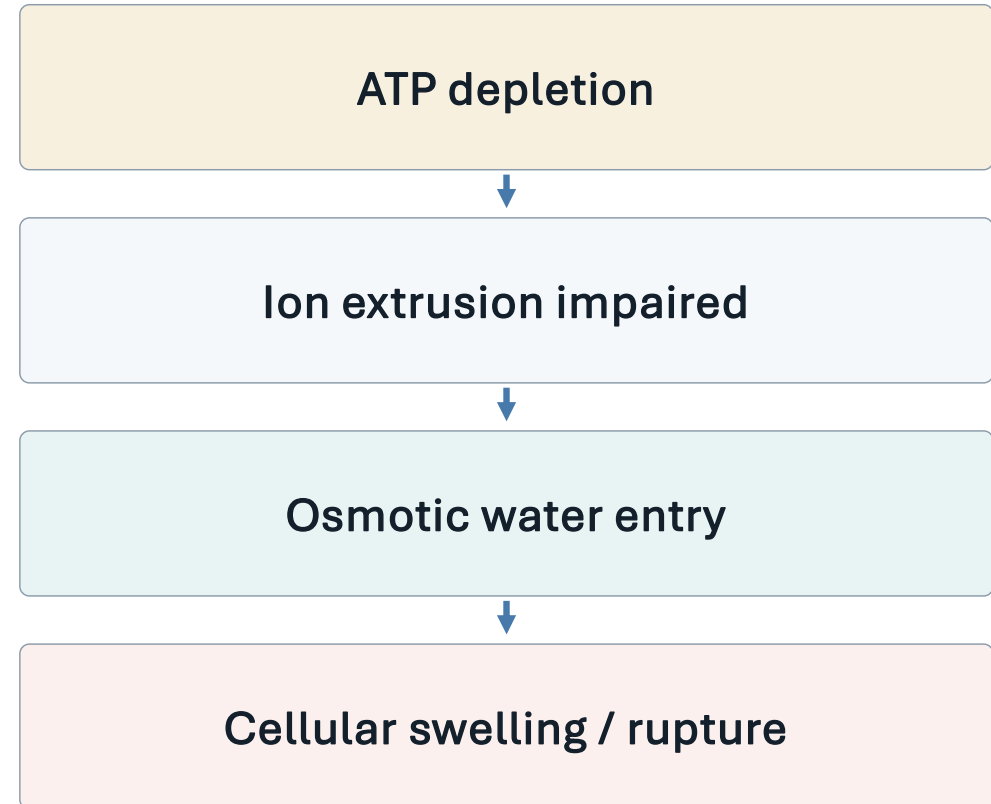
Ischemia can cause osmotic swelling

- Ischemia limits the cell's ability to generate energy.
- ATP-dependent ion extrusion becomes insufficient.
- Water accumulates and the cell swells.



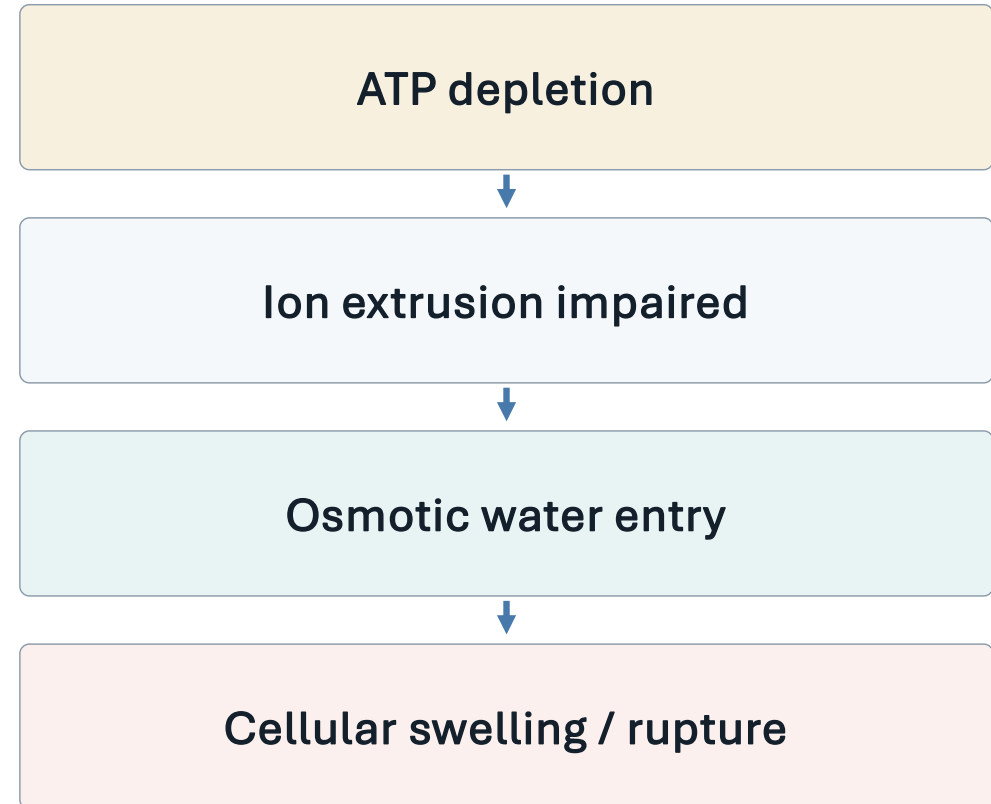
Toxic injury can disrupt ion homeostasis

- Certain toxins impair energy-dependent cell functions.
- Reduced ion pumping permits osmotic water entry.
- Persistent swelling can progress to rupture.



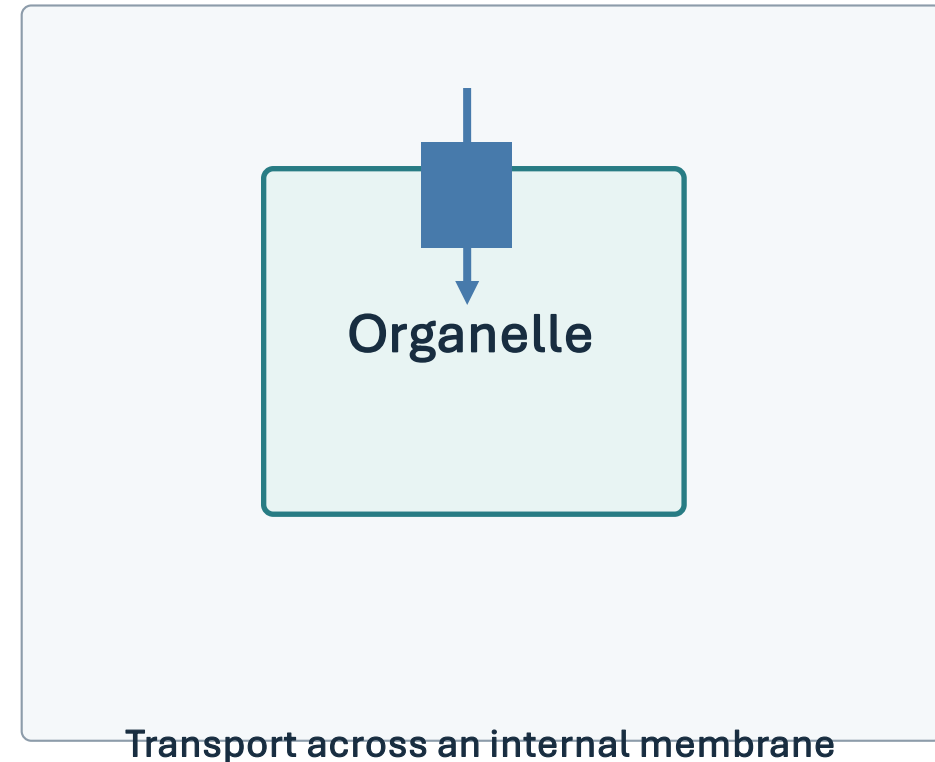
From pump failure to membrane rupture

- Inorganic-ion removal becomes inadequate.
- Intracellular osmotic pressure favors water entry.
- The resulting swelling may culminate in cell rupture.



Ca^{2+} transport regulates cellular processes

- Specialized transport systems control ion concentration.
- Cytosolic enzymes can be regulated by Ca^{2+} .
- Ion homeostasis affects cellular function beyond volume.



Cytosolic enzymes have a pH optimum

- Transport helps control intracellular H^+ .
- Many cytosolic enzymes are most active around pH 7.4.
- Compartment-specific ion regulation supports enzyme activity.

Cytosol: ~pH 7.4

Lysosome: PH ≤ 5

Lysosomes require an acidic compartment

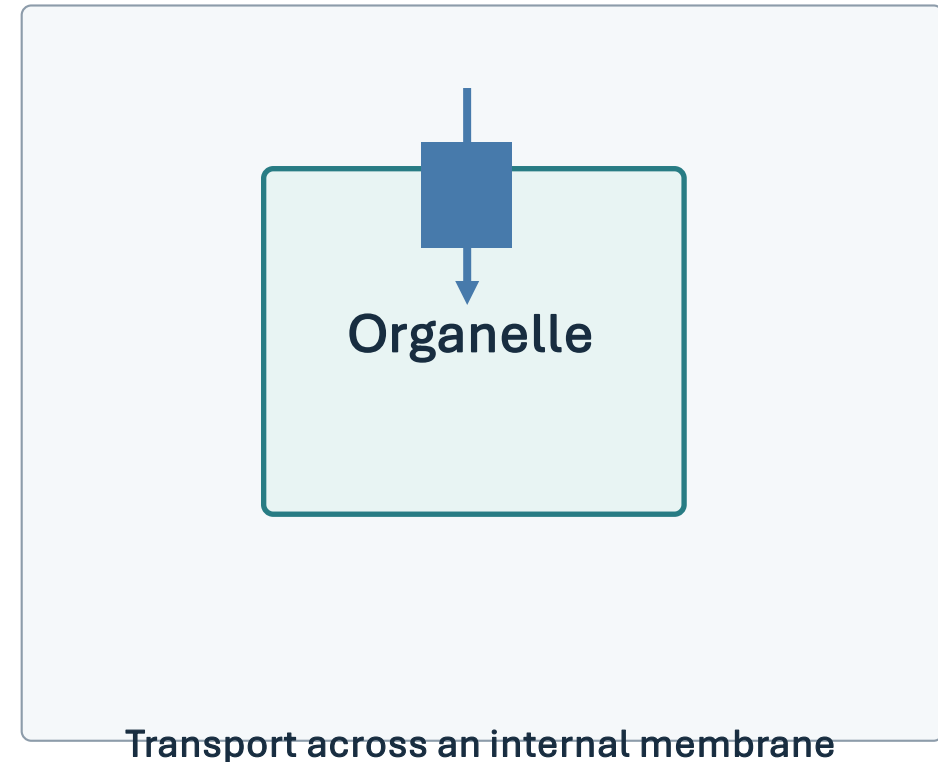
- Lysosomal enzymes function best at approximately pH 5 or less.
- Internal membranes help maintain distinct conditions.
- Cellular compartments depend on selective ion transport.

Cytosol: ~pH 7.4

Lysosome: PH ≤ 5

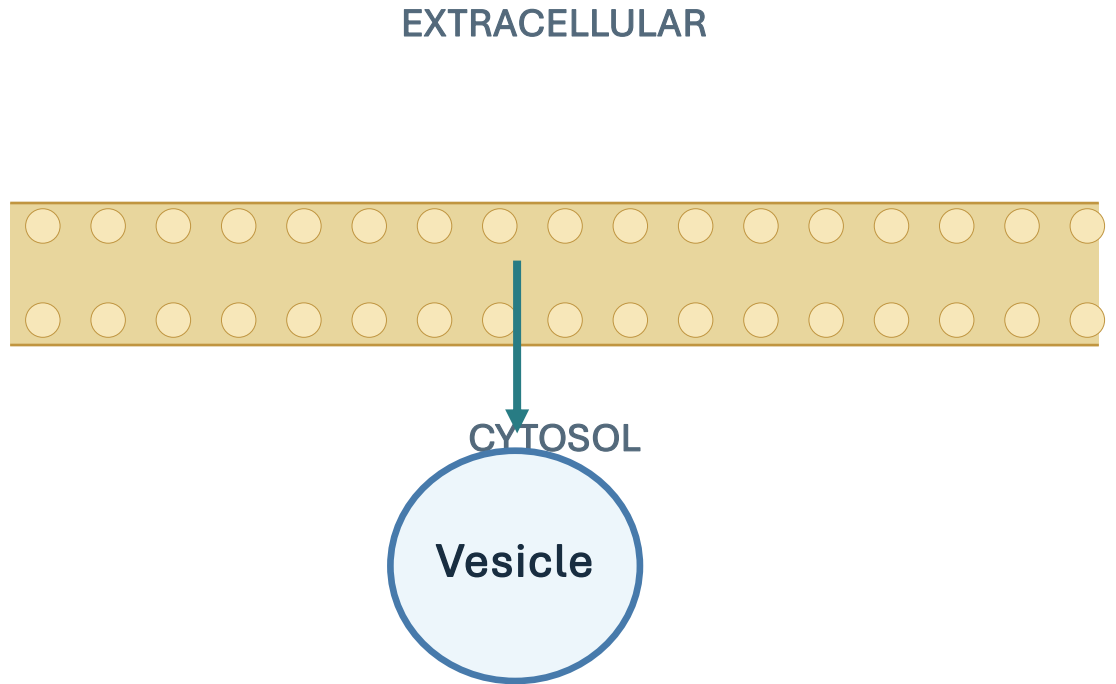
Transport also occurs across organelle membranes

- Channels and pores are not confined to the plasma membrane.
- Membrane-separated compartments require controlled exchange.
- Distinct ion concentrations support specialized functions.



Bulk uptake is a different transport mode

- Channels and carriers handle small solutes and ions.
- Endocytosis internalizes fluid or larger material in vesicles.
- Phagocytosis and pinocytosis represent forms of uptake.



Large material packaged in vesicles

Clinical mechanism check: Swelling

A cell exposed to an energy-depleting insult develops progressive swelling. Which sequence best explains it?

A. Reduced ion extrusion → osmotic water entry

B. Increased Na^+ pumping → cell dehydration

C. An open solute channel → active ion export

D. Decreased intracellular osmolarity → water entry

Osmotic swelling follows ion-pump failure

A. Reduced ion extrusion → osmotic water entry

- Energy deprivation compromises ion-pump activity.
- Intracellular osmotic burden promotes hydration.
- Severe swelling may ultimately cause rupture.

Mechanism check: Channel or carrier?

Select the statement consistent with Robbins' transport description.

A. All channels can pump solutes uphill

B. Carriers must consume ATP for every movement

C. Open channels permit rapid gradient-driven movement

D. All small molecules cross the bilayer freely

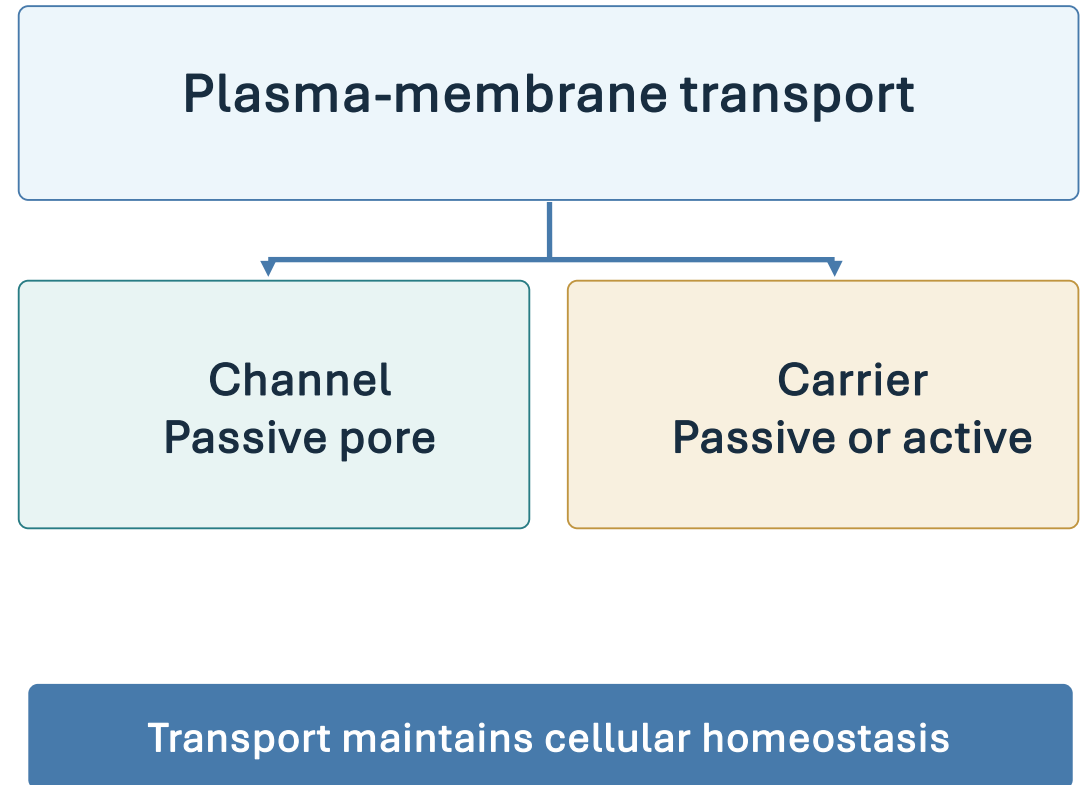
Channels enable rapid passive transfer

C. Open channels permit rapid gradient-driven movement

- A hydrophilic pore allows rapid passage when open.
- Carrier proteins bind substrate and undergo shape changes.
- Active uphill transport requires a carrier.

An integrated model of membrane transport

- Permeability determines whether proteins are needed.
- Gradient direction distinguishes passive from active transport.
- ATPases maintain the ionic conditions on which cells depend.
- Ion homeostasis determines cell volume and enzyme function.



Five principles to retain

- Channels create selective hydrophilic pores.
- Carriers bind solutes and change shape.
- Only carriers mediate active uphill transport.
- Na^+ gradients drive intestinal and renal nutrient uptake.
- Loss of ATP-dependent ion control causes osmotic swelling.

Primary reference and source scope

Robbins, Cotran & Kumar: Pathologic Basis of Disease

11th edition (2026) • Chapter 1: The Cell as a Unit of Health and Disease

- Core section: “Carriers and Channels,” pp. 9–10.
- Introductory background: “Membrane Transport” and “Passive Diffusion,” p. 9.

All diagrams are original, editable schematics. Clinical questions are hypothetical teaching applications of the cited principles.