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Charting New Horizons in Education

Transport - II

03

Physiology

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Na^+ + K^+ - Pump

1. **Maintains high K+ and low Na+ concentrations inside the cell:**

- Uses ATP energy to transport 3 Na+ ions out and 2 K+ ions in.
- Essential for maintaining proper ion gradients for processes like resting membrane potential and action potentials.

2. **Maintains intracellular negativity:**

- Contributes to the negative resting membrane potential by exporting 3 Na+ for every 2 K+ imported.
- Helps establish the -70 mV resting membrane potential, crucial for cell excitability (especially in neurons and muscle cells).

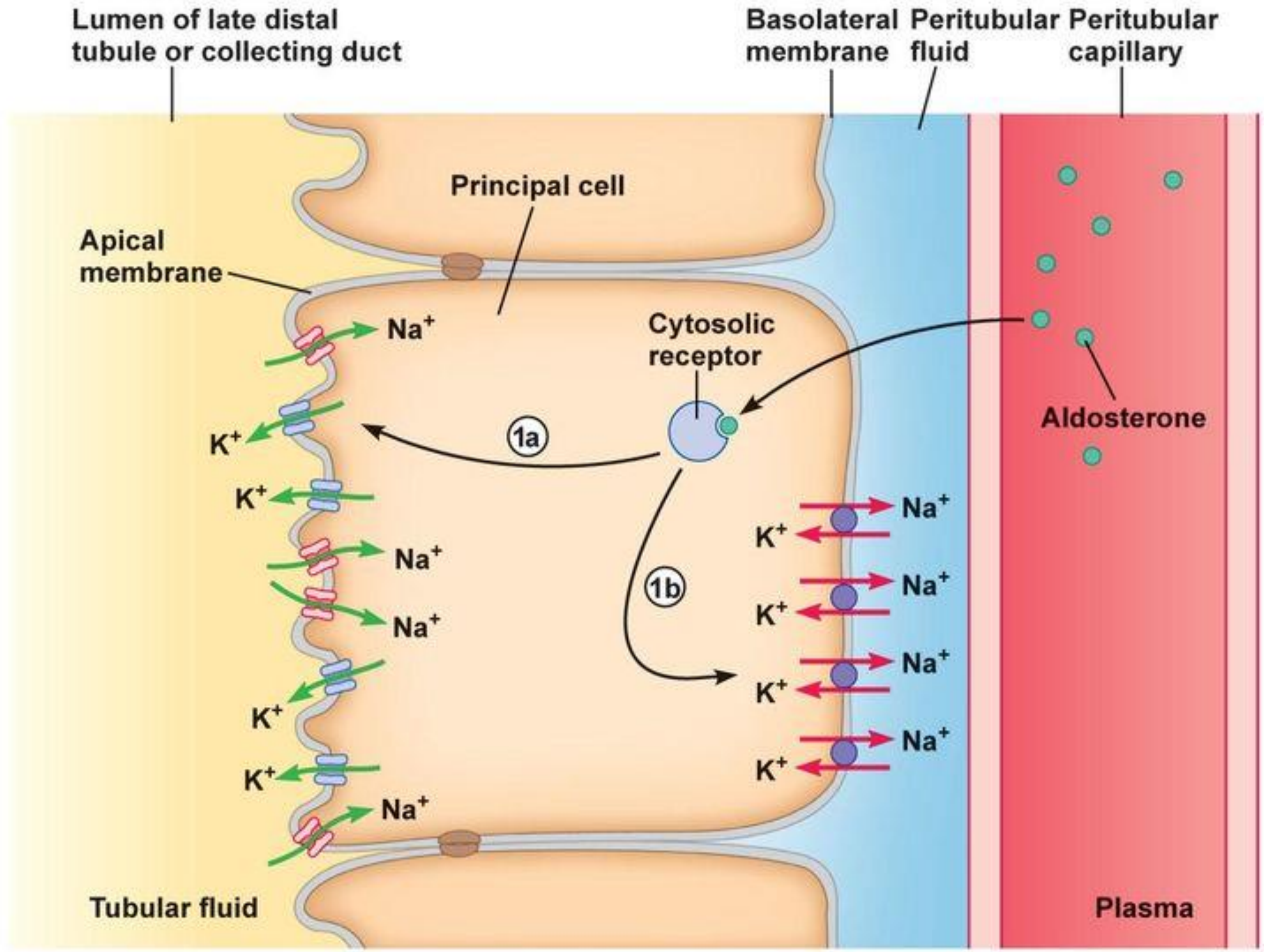
3. **Maintains cell volume:**

- Regulates osmotic balance by removing Na+ from the cell, preventing excessive water influx that could cause cell swelling.
- Vital for osmoregulation; dysfunction can lead to cell swelling (e.g., ischemia or disease states).

4. **Activates the Carrier Protein:**

- Functions as a primary active transporter using ATP to move Na+ and K+ across the membrane.
- The ion gradient it creates powers secondary active transporters, enabling the movement of other molecules into and out of the cell.

Na^+ + K^+ - Pump



Lumen of late distal tubule or collecting duct
Basolateral membrane
Peritubular fluid
Peritubular capillary
Principal cell
Apical membrane
Na+
K+
K+
Na+
Na+
K+
K+
Na+
Cytosolic receptor
1a
1b
Aldosterone
Na+
K+
Na+
K+
Na+
K+
Na+
K+
Tubular fluid
Plasma

Na^+ + K^+ - Pump

1. **Sodium Transport from the Lumen (Apical Membrane):**

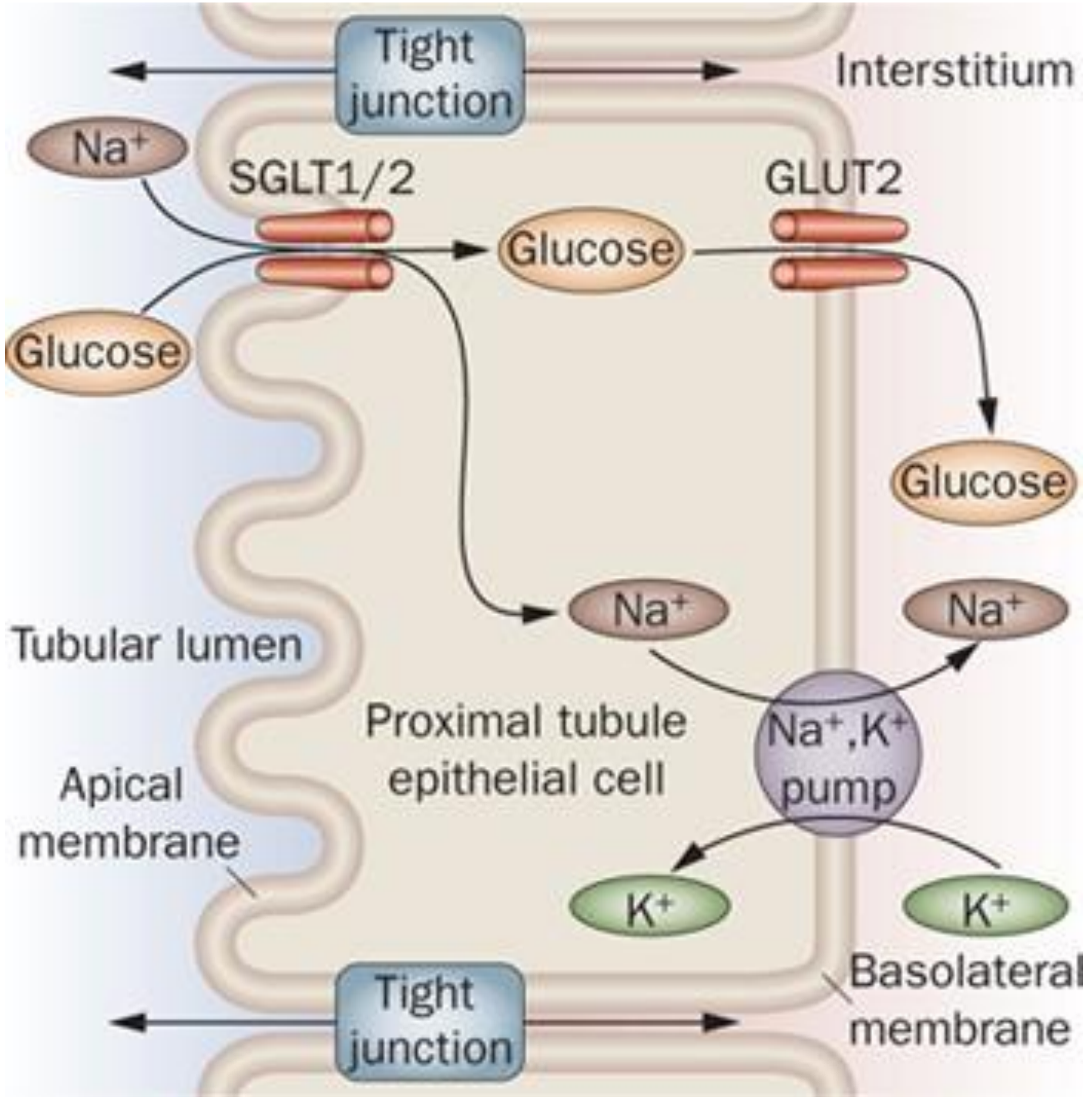
- In polarized epithelial cells (e.g., kidneys, intestines, lungs), Na^+ enters the cell from the lumen via specialized transporters on the apical membrane.

2. **Sodium Movement to the Basolateral Membrane:**

- After entering the epithelial cell through the apical membrane, Na^+ ions are transported to the basolateral membrane (facing the underlying tissue or capillaries).
- The Na^+ ions will eventually enter the bloodstream through capillaries by crossing the basolateral membrane.

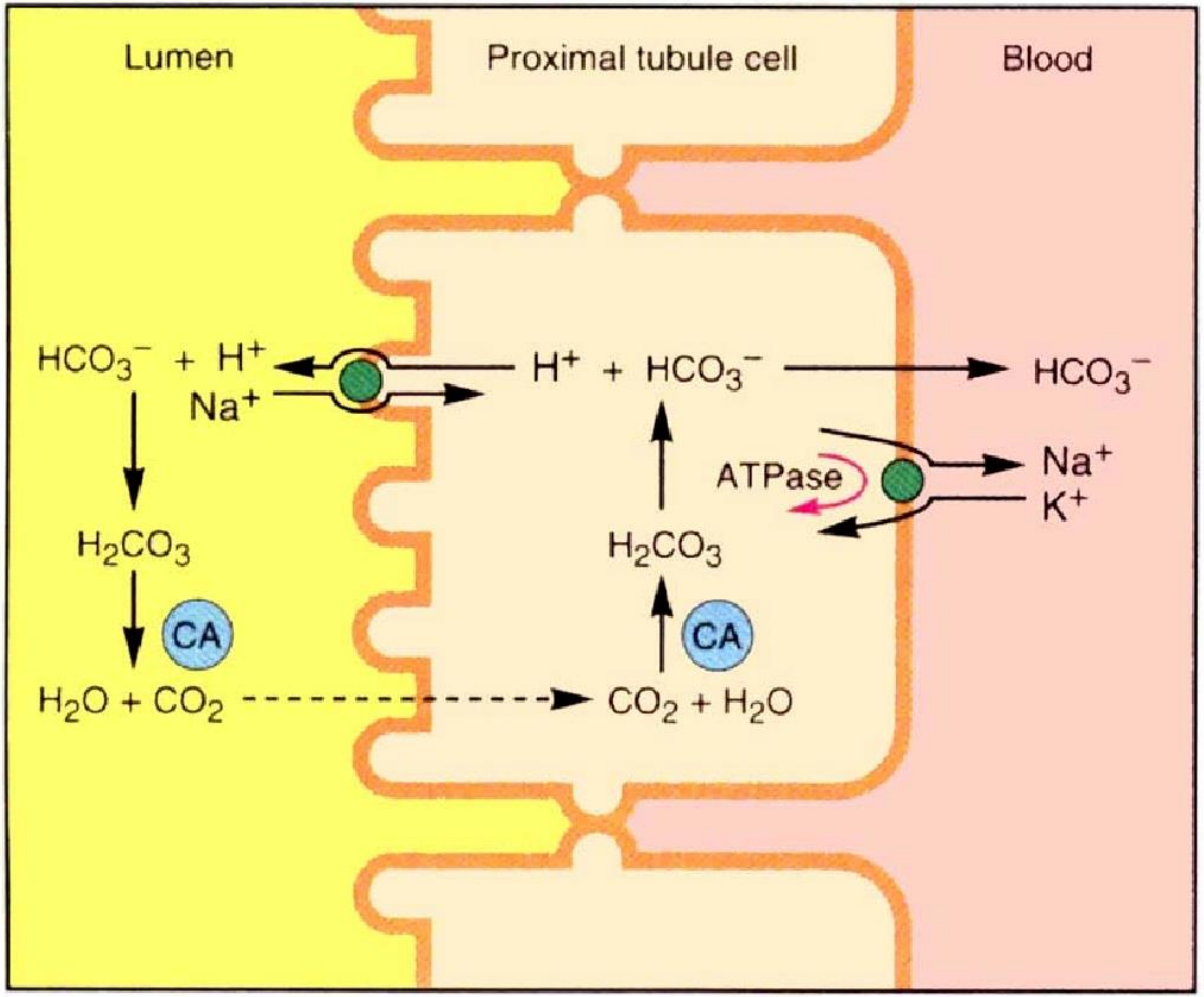
3. **Na+/K+ ATPase Pump on the Basolateral Membrane:**

- The Na+/K+ ATPase pump on the basolateral membrane actively transports Na^+ out of the cell and K^+ into the cell.
- It works by: Actively transporting 3 Na^+ ions out of the cell into the extracellular space (or blood), using ATP, Actively transporting 2 K^+ ions into the cell.


Tight junction
Interstitium
Na+
SGLT1/2
GLUT2
Glucose
Glucose
Glucose
Na+
Na+
Tubular lumen
Proximal tubule epithelial cell
Na+,K+ pump
Apical membrane
K+
K+
Basolateral membrane
Tight junction

Co-transport - Symport

1. **<u>Na^+ moves downhill:</u>** The Na+/K+ ATPase pump creates a high concentration of Na^+ outside the cell and a low concentration inside.
2. **<u>Symporter binds Na^+ and target molecule:</u>** The symporter (e.g., Na+/glucose symporter) binds Na^+ from the extracellular space (lumen) and another molecule (e.g., glucose) from inside the cell.
3. **<u>Conformational change:</u>** The binding of Na^+ and the target molecule causes the symporter to change shape.
4. **<u>Na^+ and target molecule move together:</u>** Na^+ moves down its concentration gradient (from high outside to low inside) while the target molecule (e.g., glucose) is transported against its concentration gradient (from low concentration in the lumen to high concentration inside the cell).
5. **<u>Energy transfer:</u>** The energy from Na^+ moving downhill is used to drive the uphill transport of the target molecule.


Lumen
Proximal tubule cell
Blood
HCO3⁻ + H⁺
Na⁺
H⁺ + HCO3⁻
HCO3⁻
ATPase
Na⁺
K⁺
H2CO3
CA
H2O + CO2
H2CO3
CA
CO2 + H2O

Counter-transport

- **<u>Mechanism Involving Carbonic Anhydrase in Na+/H^+ Countertransport:</u>**

1. Inside the Cell:

- Inside the cell, Na^+ is actively transported out of the cell by the Na+/K+ ATPase pump, creating a high concentration of Na^+ outside the cell and a low concentration inside.
- This gradient allows Na^+ to enter the cell via the Na+/H^+ exchanger, which brings Na^+ into the cell while pumping H^+ out of the cell.

2. **<u>H^+ Excretion:</u>**

- The Na+/H^+ exchanger works by exchanging Na^+ moving into the cell for H^+ moving out of the cell, helping maintain intracellular pH.
- However, for this exchange to effectively regulate the pH, the H^+ must be buffered, and carbonic anhydrase is involved in this process.

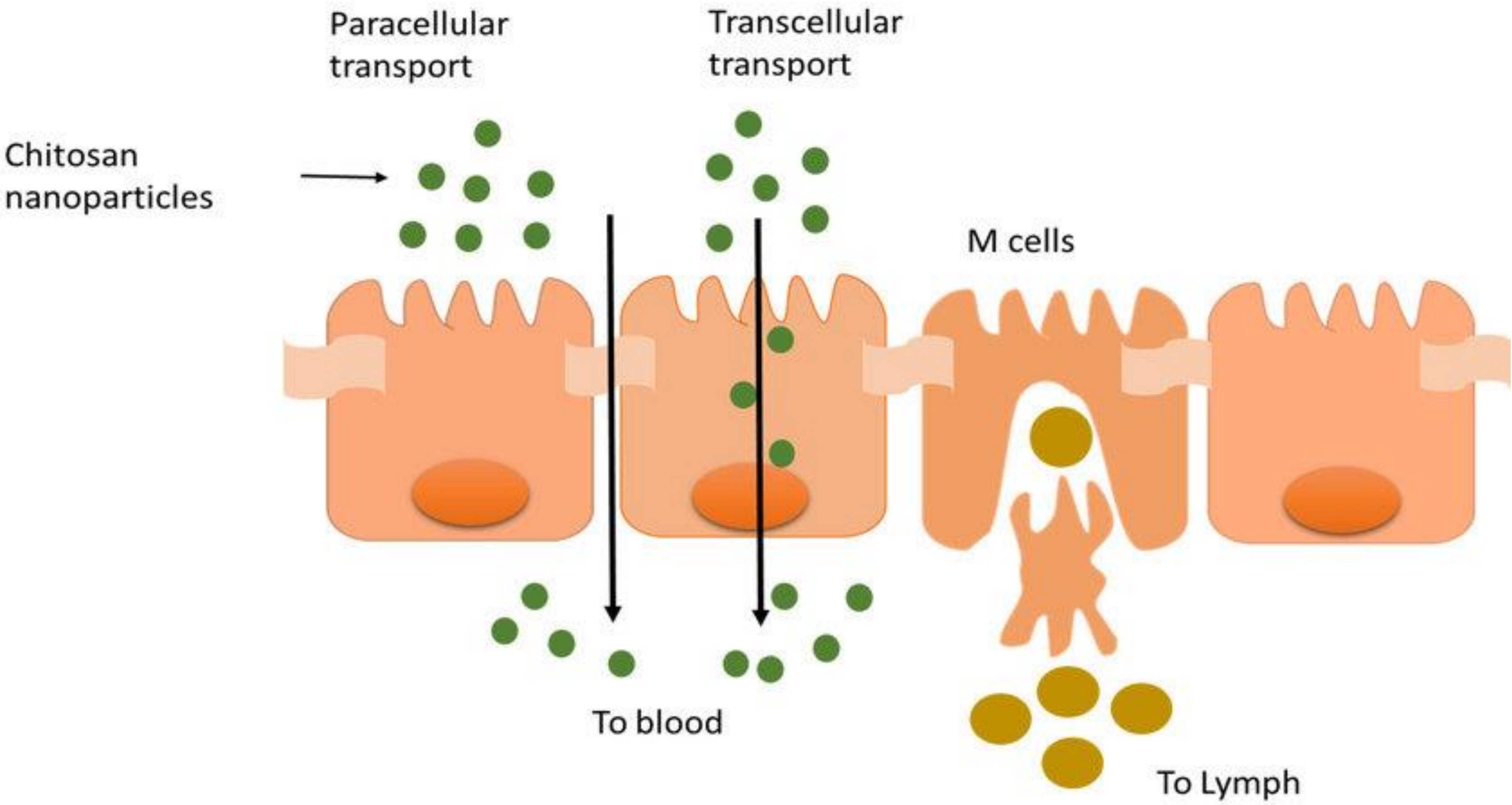
Counter-transport

3. Role of Carbonic Anhydrase (CA):

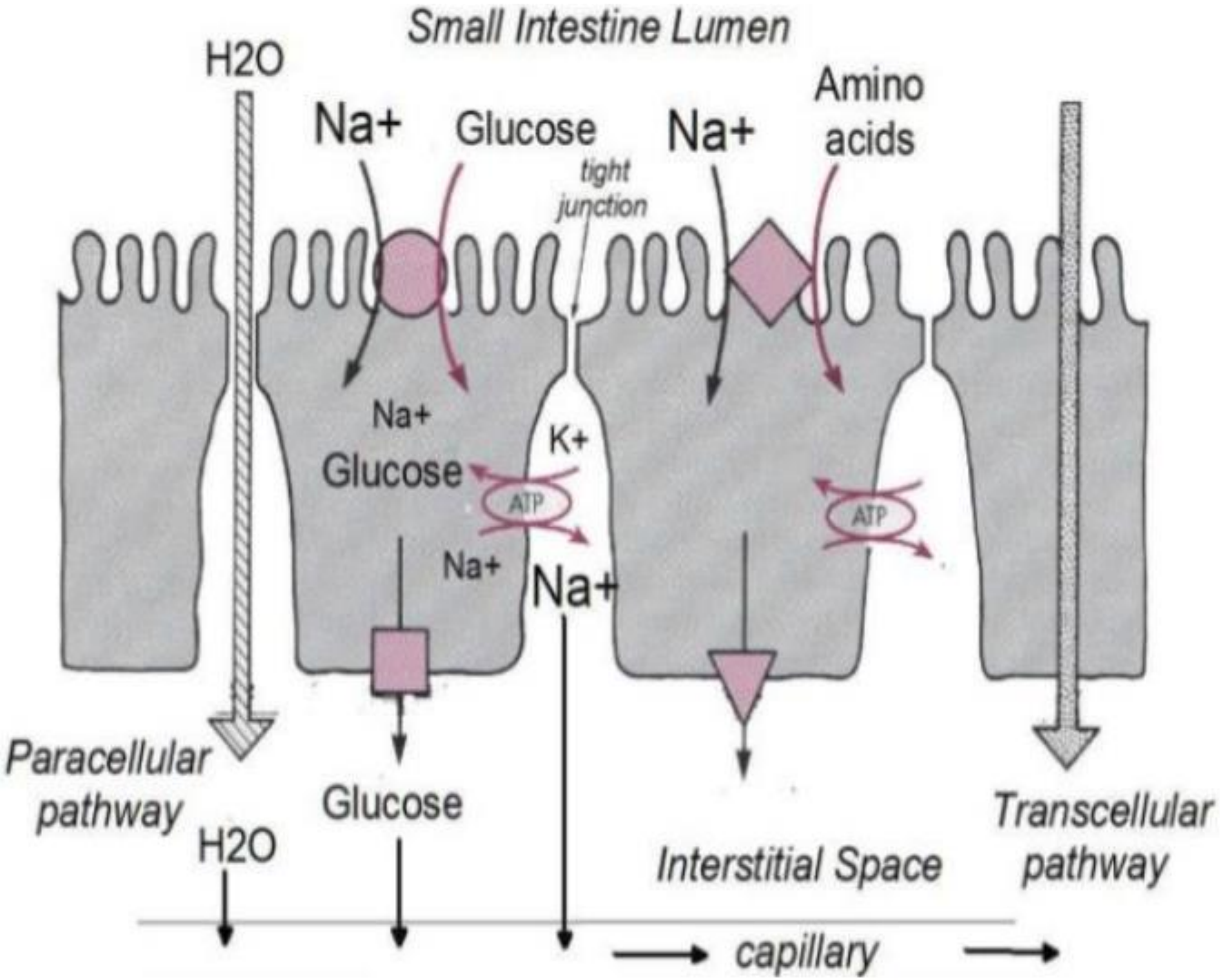
- Inside the cell, carbonic anhydrase catalyzes the reaction:
- $CO_2 + H_2O \leftrightarrow H_2CO_3$ (carbonic acid) $\leftrightarrow H^+ + HCO_3^-$
- This reaction ensures there is a ready supply of H^+ to be exchanged by the Na+/H^+ exchanger.
- Additionally, HCO_3^- formed inside the cell is transported out of the cell, often via bicarbonate transporters, and helps maintain the overall acid-base balance.

4. Buffering Effect:

- As H^+ is excreted by the Na+/H^+ exchanger (into the extracellular space), it can combine with bicarbonate (HCO_3^-) to form carbonic acid, which is eventually converted back to CO_2 by carbonic anhydrase, facilitating the exhalation of CO_2 in tissues like the kidneys and lungs.



Paracellular transport
Transcellular transport
Chitosan nanoparticles
M cells
To blood
To Lymph


Small Intestine Lumen
H2O
Na+
Glucose
tight junction
Na+
Amino acids
Na+
Glucose
K+
ATP
Na+
Na+
ATP
Paracellular pathway
Glucose
H2O
Interstitial Space
Transcellular pathway
capillary

Transcellular vs. Paracellular

- **Tight Junctions:** Paracellular transport occurs through the tight junctions of the neighboring epithelial cells, which can be leaky or tight, based on the type of tissue.

- **Transcellular Transport Creates Osmotic Gradients:**
- As ions (e.g., Na^+, Cl^-, HCO_3^-) and other solutes are actively or passively transported across the epithelial cell membrane (via transcellular transport), they create an osmotic gradient between the intracellular and extracellular spaces (or between lumen and blood).

- **Water Follows Solutes:**
- Due to this osmotic gradient, water moves passively through the tight junctions via the paracellular pathway to balance the osmotic pressure between the compartments.

Transcellular vs. Paracellular

- **Passive Movement:**
- Water moves passively through the paracellular space, following solute movement to maintain tissue fluid balance.

- **Role of Permeability:**
- The tight junction permeability is a key factor determining the degree to which water may pass through the paracellular route. Leaky tight junctions (e.g., in kidney proximal tubule or intestinal epithelium) allow more water passage, while tighter junctions (e.g., in kidney distal tubule) restrict water flow.

- **Example in Kidneys:**
- In the proximal convoluted tubule of the kidney, Na^+ is actively transported out of the tubular lumen. This creates an osmotic gradient that pulls water through the paracellular pathway into the interstitial space and thus into the blood.

«Wherever the art of medicine is loved, there is also a love of humanity.»

- Hippocrates-

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