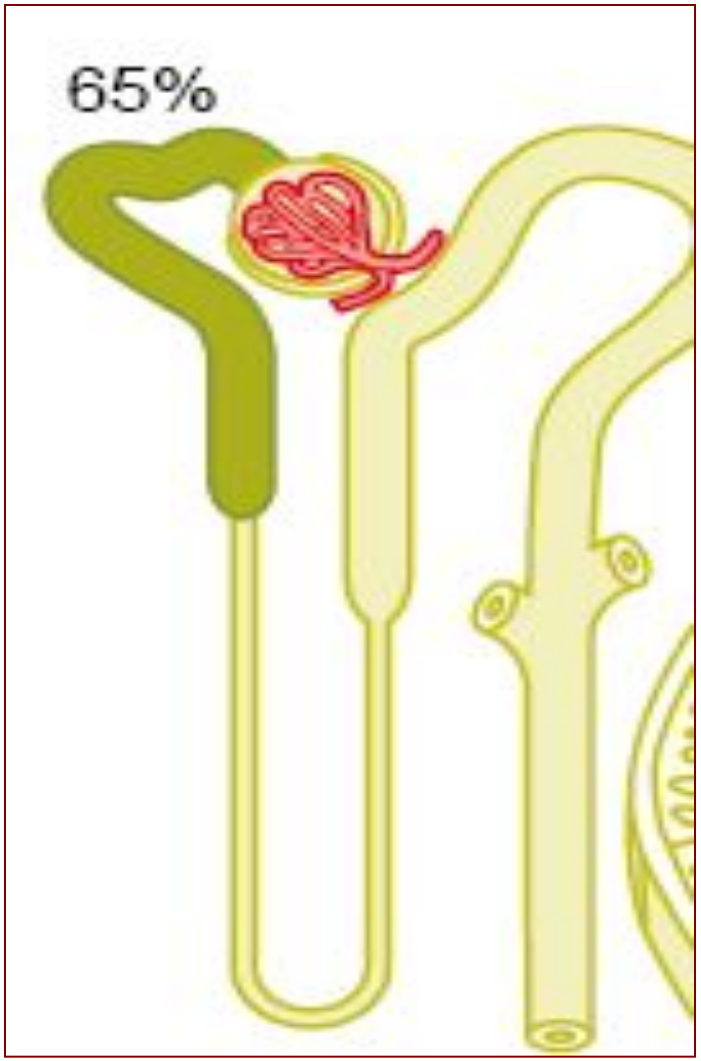
Tubular reabsorption & secretion

1. PCT
2. Loop of Henle
   I) Thin descending limb
   II) Thin ascending limb
   III) Thick ascending limb
3. DCT
4. Collecting duct ---i) Cortical CT
   ii) Meddulary CT

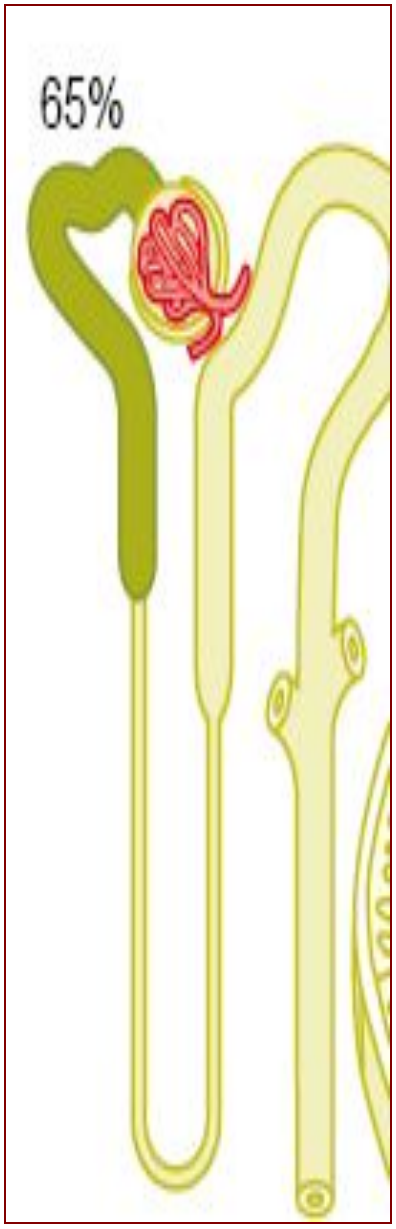
PCT reabsorption

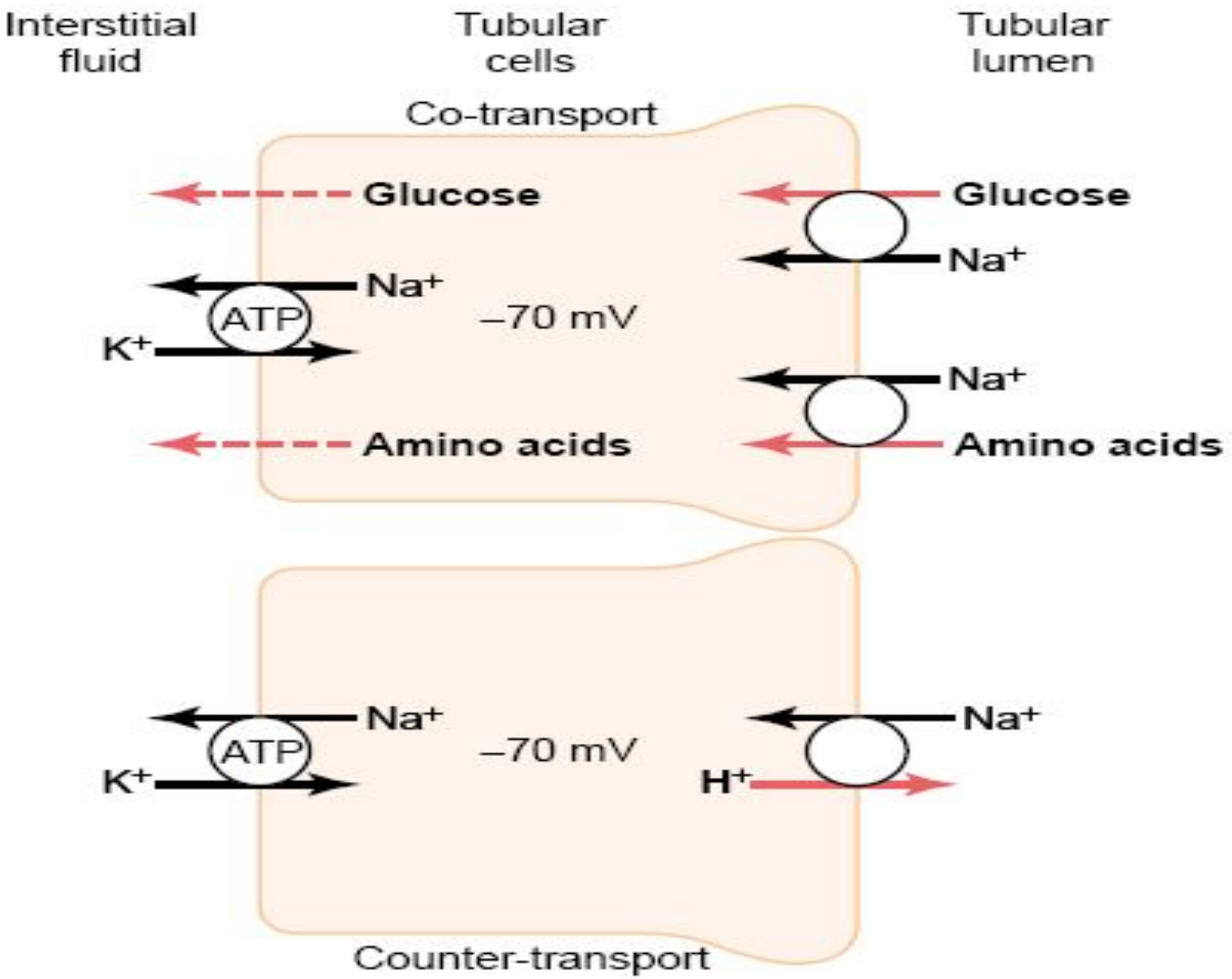
- PCT epithelial cells have brush border with microvilli,
- Highly metabolic with large no. of mitochondria.
- Presence of protein carrier molecules.
- 65% of filtered load are reabsorbed by PCT.



PCT

- **Reabsorption**
  - 65% Na+,H20, 64% Cl-.
  - 85% HCO3-, 65% K+
  - 100% glucose, amino acids (Na+ co transport) Pi , lactates.
  - 50% urea.
- **Secretion**
  - Organic acids & bases
  - H+ secretion ---(Na+ - H+ counter transport)
- **Osmolarity change –**
  - As both solutes and fluid are absorbed, fluid remains isosmotic (300 mOsm/L) in PCT.

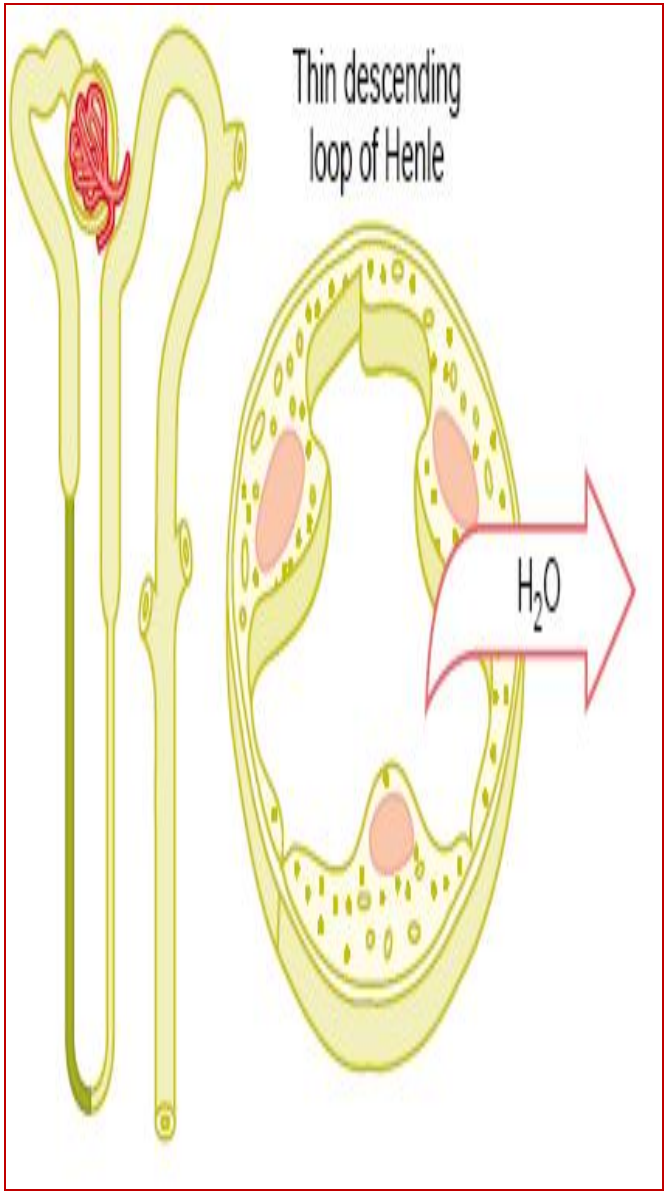



Interstitial fluid
Tubular cells
Tubular lumen
Co-transport
Glucose
Glucose
Na+
Na+
ATP
K+
–70 mV
Na+
Amino acids
Amino acids
Na+
ATP
K+
–70 mV
Na+
H+
Counter-transport

- **Effect of hormones-**
- **Angiotensin II** = Increase Nacl, H2O reabsorption, increase H+ secretion)
- **Parathyroid hormone =** Increase Ca++ reabsorption and decrease PO4 reabsorption.

Functions

1. The **descending limb of Henley's loop** is very **permeable to water** but not to solutes.
2. The **thin ascending limb** is relatively **impermeable to water** but permeable to Na^+ and Cl **--- Passive transport of Na+ & cl-.**



3. **Thick ascending limb**

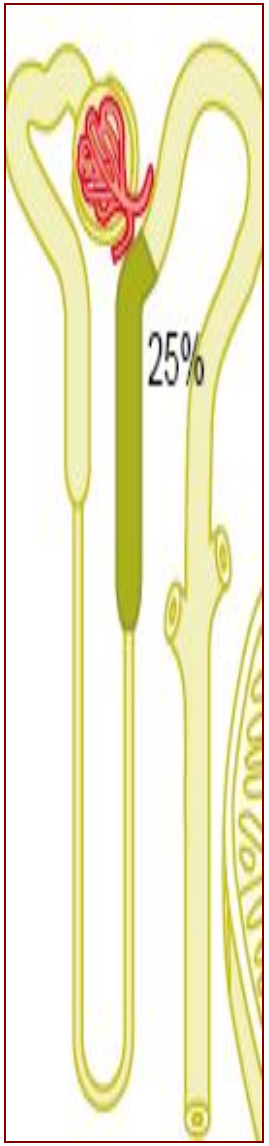
i) It is capable of active reabsorption of **25%** of total filtered sodium, chloride, and potassium ---- **1 Na+ ,2 Cl, 1 K+ co transporter.**

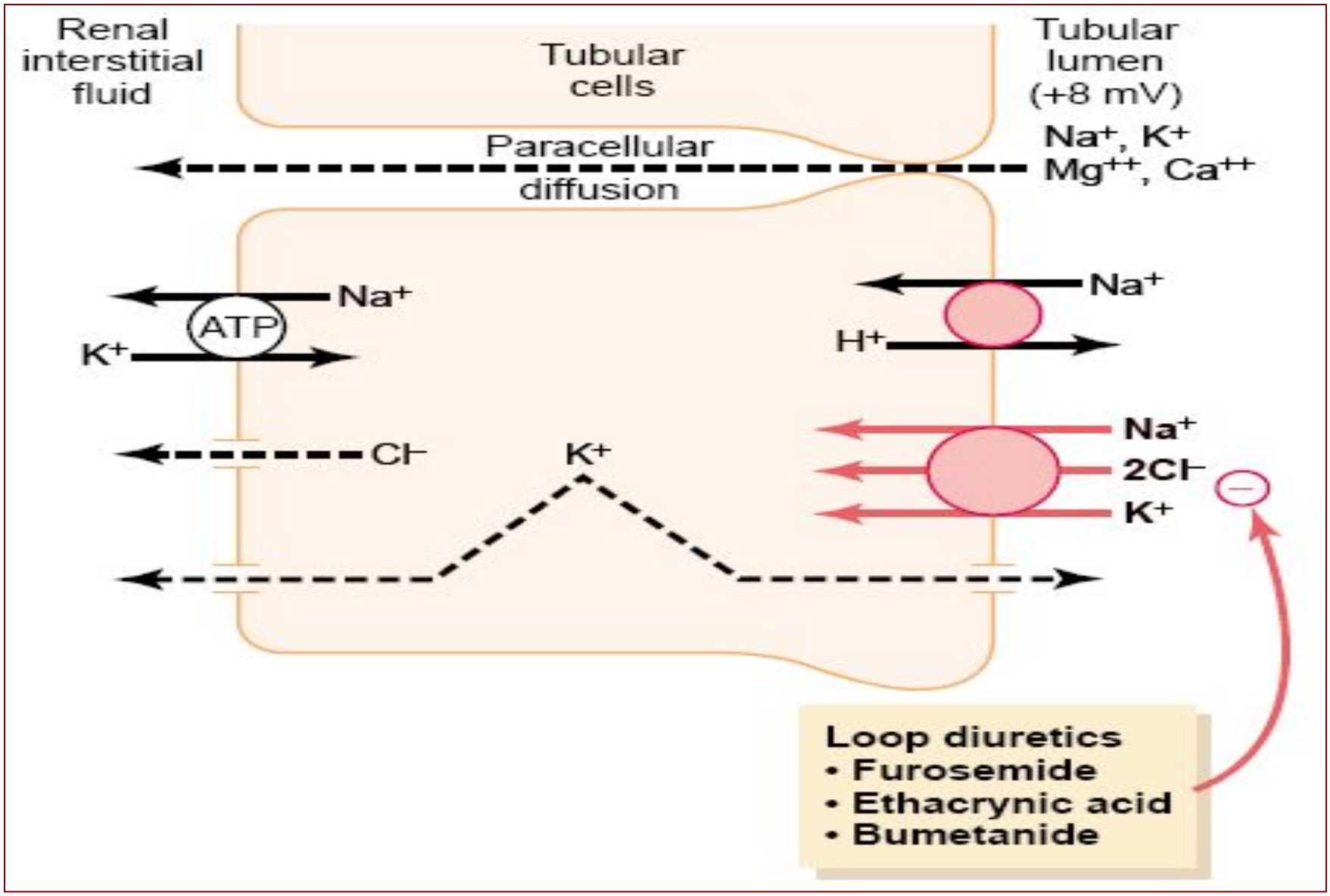
ii) This part is **impermeable to water**.

iii) There is also significant **paracellular reabsorption of cations, such as Mg++, Ca++, Na+, and K+.**

iv) **Na+ - H+ counter transport**

-Na+ - H+ counter-transport mechanism in its luminal cell membrane that mediates **sodium reabsorption and hydrogen secretion in this segment.**




Renal interstitial fluid
Tubular cells
Tubular lumen (+8 mV)
Na+, K+
Mg++, Ca++
Paracellular diffusion
Na+
ATP
K+
H+
Na+
Cl–
K+
Na+
2Cl–
K+
–
Loop diuretics
• Furosemide
• Ethacrynic acid
• Bumetanide

Osmolarity change- fluid leaving ascending loop of Henle into the early distal tubule is **hypo-osmotic (100 mOsm/L),** with an osmolarity of only about one third the osmolarity of plasma.

- **Effect of hormones-**
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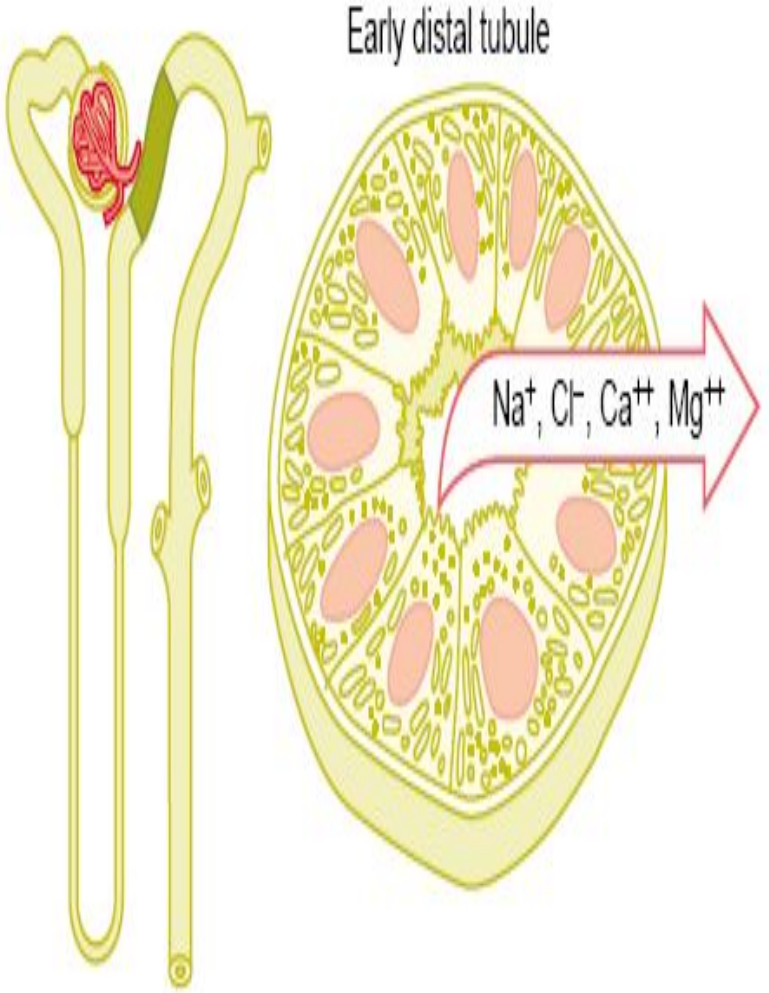
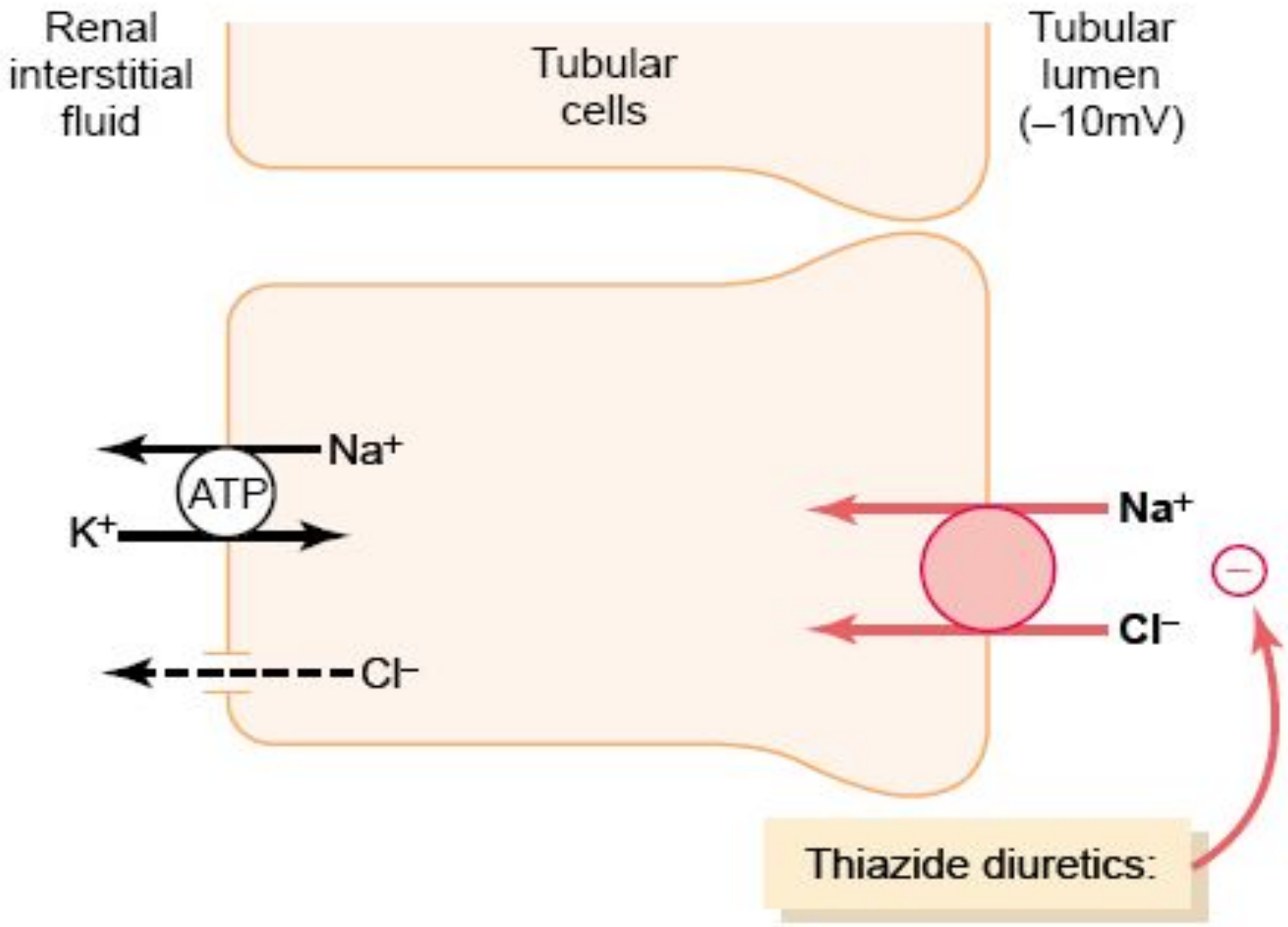
FUNCTIONS OF EARLY DCT

(i) The very first portion of the distal tubule forms part of **the juxtaglomerular complex** that provides feedback **control of GFR and blood flow.**

(ii) Approximately **5 %** of the filtered load of **sodium-chloride** is reabsorbed in the early DCT.

iii) Reabsorption of **Ca++ , Mg++.**



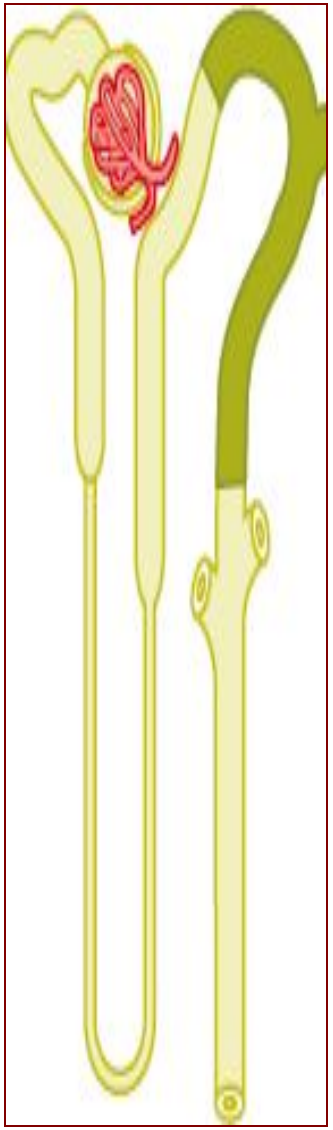

Renal interstitial fluid
Tubular cells
Tubular lumen (–10mV)
Na+
ATP
K+
Cl–
Na+
Cl–
Thiazide diuretics:

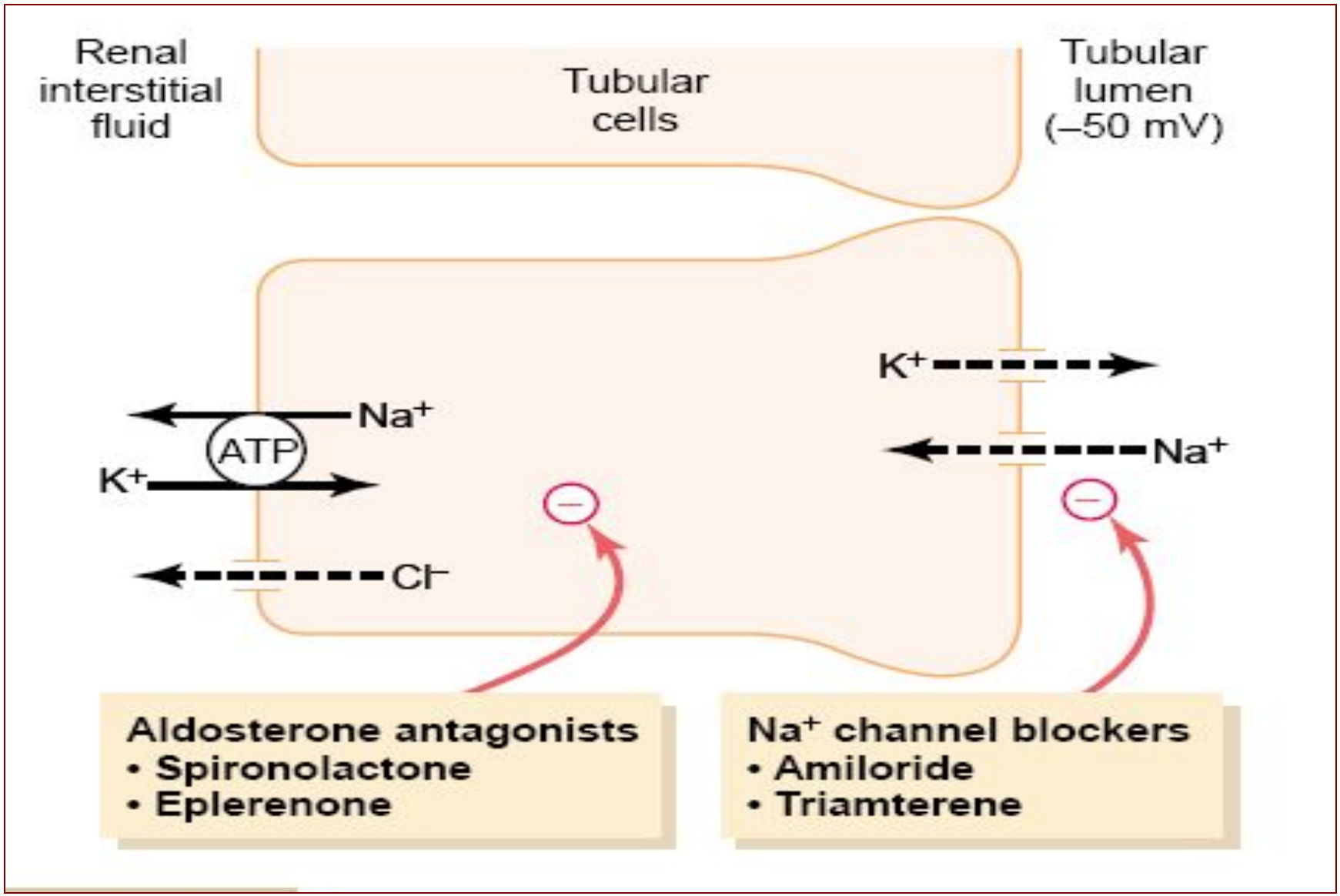
Functions of late DCT & CT

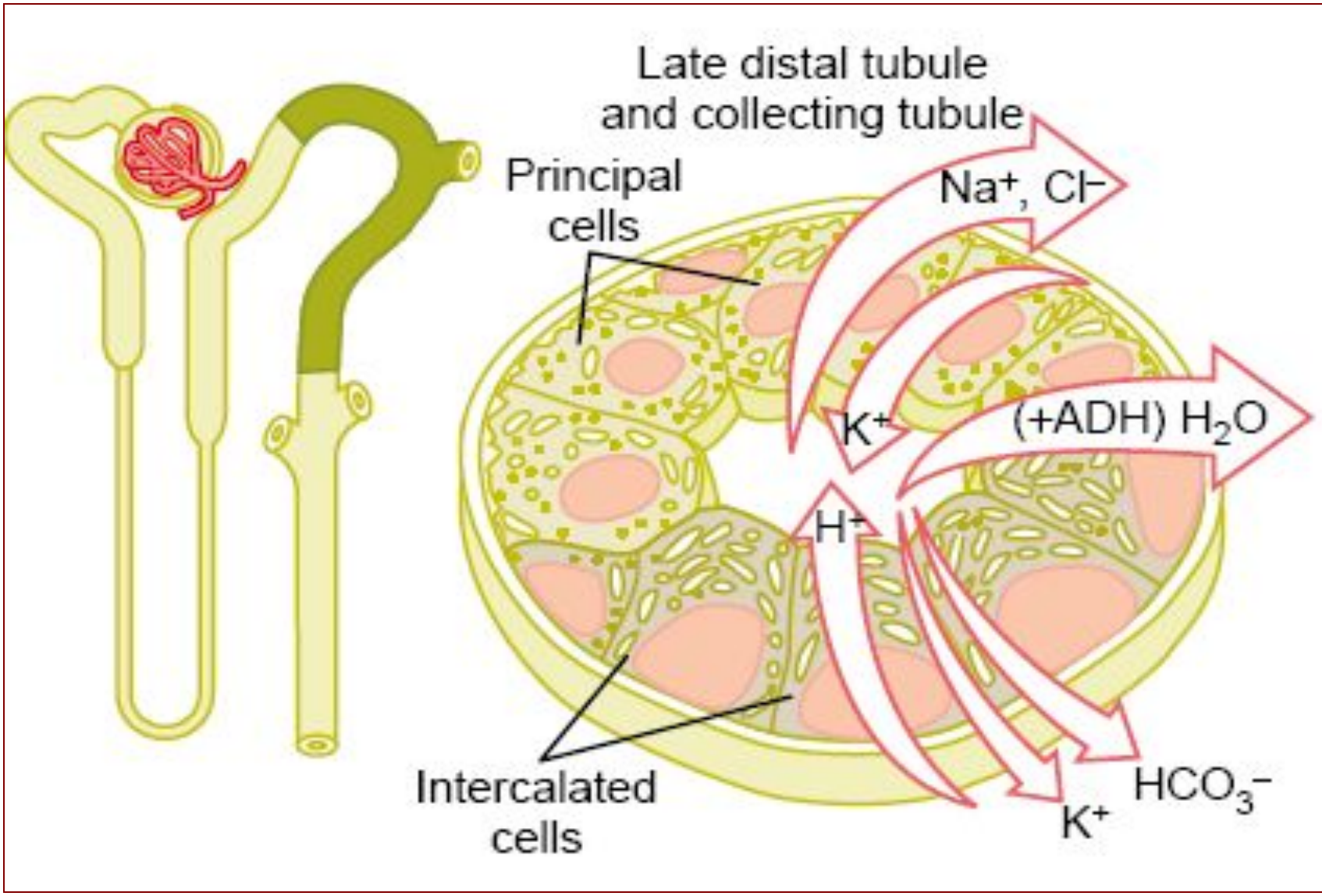
1. P cells (Principal cells)
   - Reabsorption of Na+, Cl- & water under control of ADH.
   - Secretion of K+.

   so P cells are imp. Site for regulation of body Na+, blood volume, BP & plasma K+ level.

2. I cells
   - K+ absorption & H+ secretion.
   - Regulation of acid – base balance & acidification of urine.

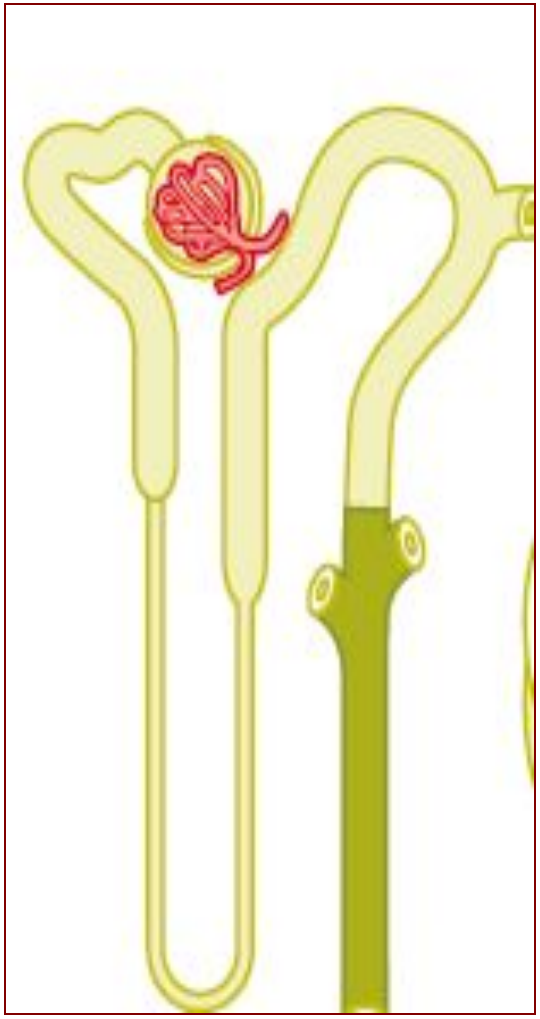



Renal interstitial fluid
Tubular cells
Tubular lumen (–50 mV)
Na+
ATP
K+
Cl–
K+
Na+
Aldosterone antagonists
• Spironolactone
• Eplerenone
Na+ channel blockers
• Amiloride
• Triamterene


Late distal tubule
and collecting tubule
Principal
cells
Na+, Cl–
K+
(+ADH) H2O
H+
Intercalated
cells
K+
HCO3–

Functions of Meddulary CT

1. It is permeable to urea.
2. Secretion of H+ ions against a large concentrated gradient --------- plays a key role in regulation of acid – base balance.
3. Reabsorption of Na+ & Cl-.
4. Under control of ADH ------
   - Permeable to water.



- In late DCT & CT osmolarity depends on the level of ADH.
- **With high level of ADH =**

i) DCT & CT --- highly permeable to water

ii) 99% water is reabsorbed.

iii) Osmolarity – 1200 -1400 mOsm/L.

iv) Formation of concentrated urine.

- **If ADH is absent**

i) DCT & CT ----- impermeable to water.

ii) 87 – 88% water is reabsorbed.

iii) Osmolarity ----- 50 mOsm/L

iv) Formation of diluted urine.

Reabsorption of sodium

1) PCT

 # First part of PCT

I) Na+ - co transport

- Na+ - glucose, Na+ - amino acid co transport.

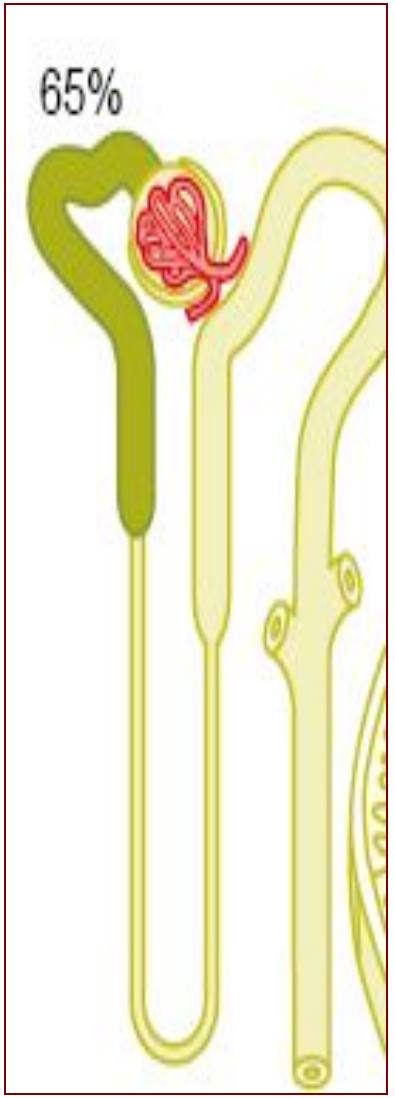
ii) Na+ - counter transport

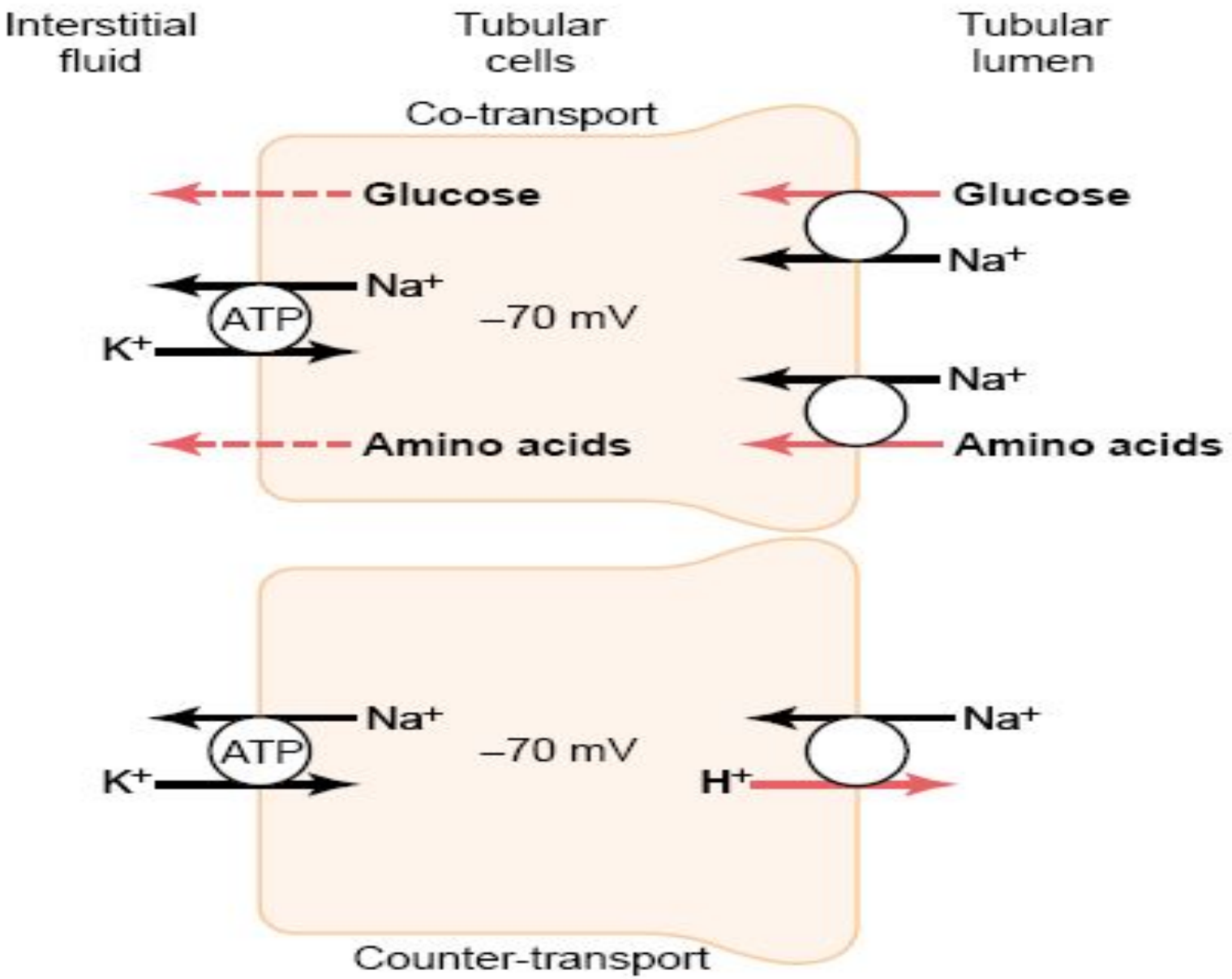
- Na+ - H+ exchange.

 # Distal part of PCT

- Cl- driven Na+ transport.

- Na+ - H+ counter transport




Interstitial fluid
Tubular cells
Tubular lumen
Co-transport
Glucose
Glucose
Na+
Na+
ATP
K+
–70 mV
Na+
Amino acids
Amino acids
Na+
ATP
K+
–70 mV
Na+
H+
Counter-transport

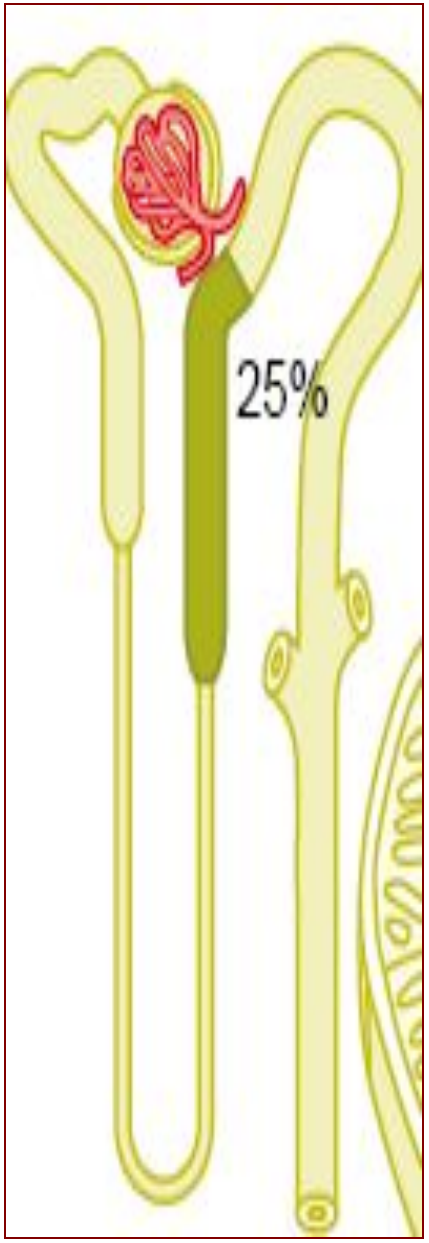
Transport of Na+ in thick segment

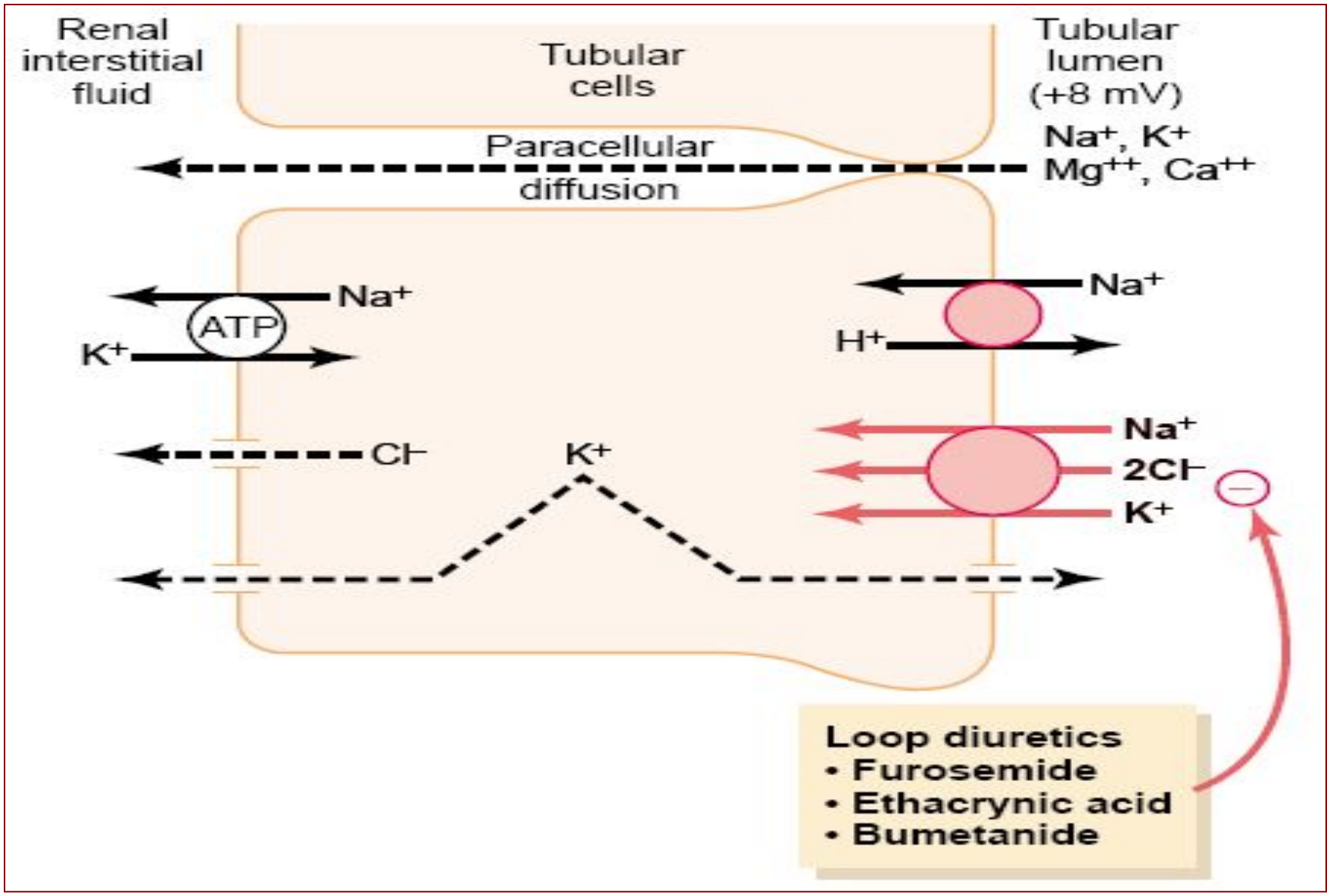
i) 1 Na+ ,2 Cl, 1 K+ co transporter in the luminal surface

- Na+ - K+ ATPase pump in the basolateral membrane.

ii) paracellular reabsorption of cations, such as Mg++, Ca++, Na+, and K+.

iii) Na+ - H+ counter transport

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K+
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Loop diuretics
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Regulation of reabsorption & secretion

1. **Glomerulotubular balance**
2. **Peritubular capillary & renal interstitial forces.**
3. **Effect of arterial BP on urine output.**

   i) Pressure Diuresis ii) Pressure Natriuresis
4. **Hormonal control**

   i) **Angiotensin II** ii) **Parathyroid hormones**

   iii) **Aldosterone** iv) **ADH** v) **ANP**
5. **Sympathetic stimulation**

Reabsorption of water

- **Obligatory reabsorption of water**

  - Passive reabsorption of water in PCT, secondary to active reabsorption of Na+ is called obligatory reabsorption of water.

- **Facultative reabsorption of water**

  - Reabsorption of water in terminal DCT & CT under control of ADH is called facultative reabsorption of water.

- **Obligatory urine volume ------- 500 ml /day.**

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- **With high level of ADH =**

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TUBULAR REABSORPTION&SECRETION

- **SELECTIVE REABSORPTION**
- **MECHANISM OF REABSORPTION**

 # Active transport

i) Primary active transport

ii) Secondary active transport

 # Passive transport

i) Simple diffusion

ii) Facilitated diffusion

Routes of reabsorption

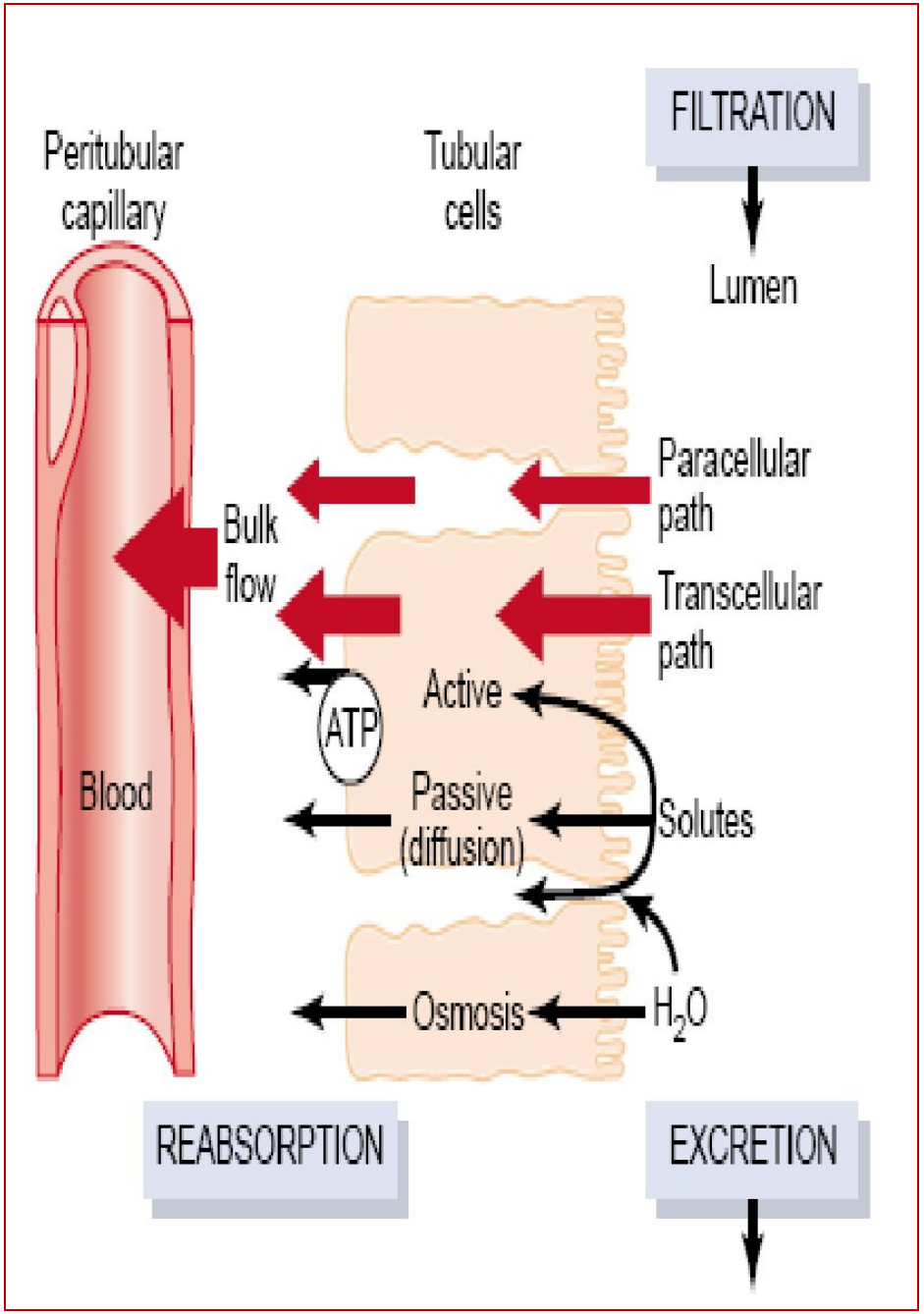
Transcellular

a) Transport from tubular lumen into the tubular cells

b) From tubular cells into interstitial fluid

c) From interstitial fluid into the capillary.

Paracellular



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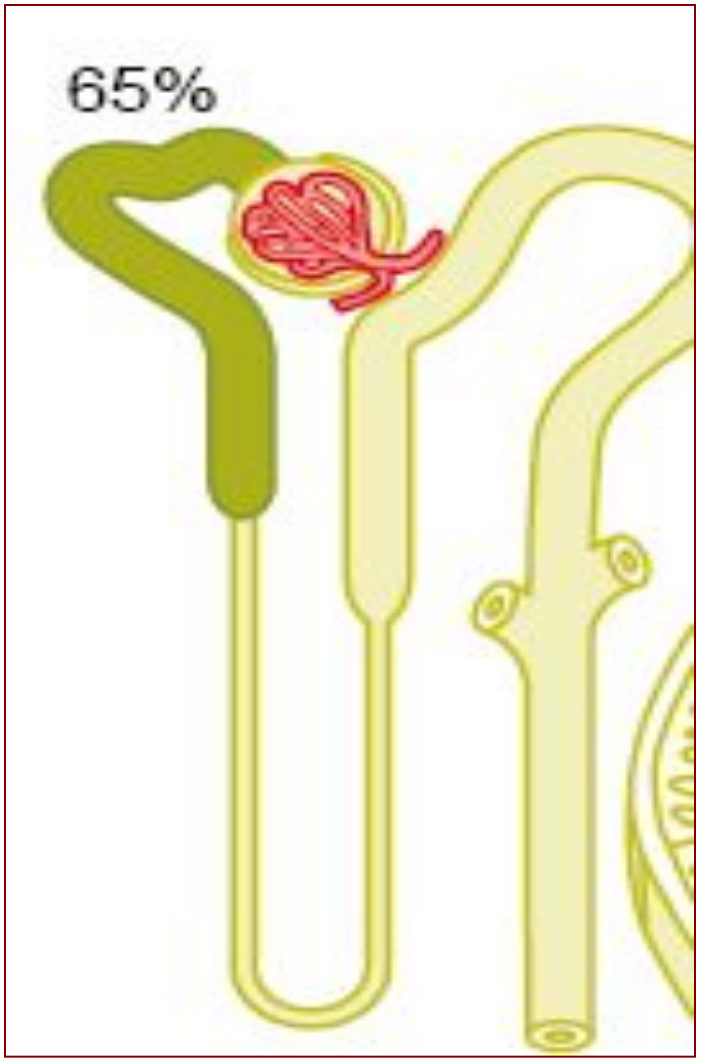
- Presence of protein carrier molecules.
- 65% of filtered load are reabsorbed by PCT.



PCT

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  - 100% glucose, amino acids (Na+ co transport) Pi , lactates.
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  - Organic acids & bases
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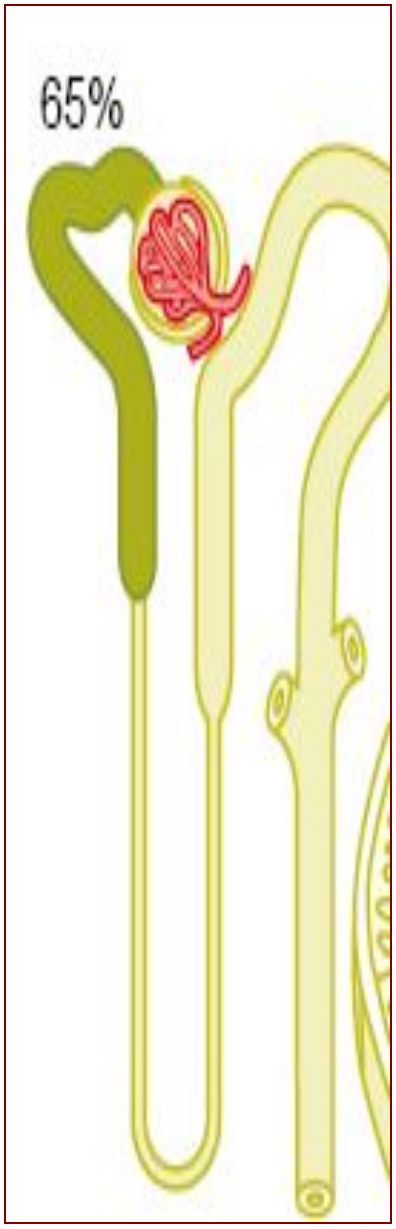
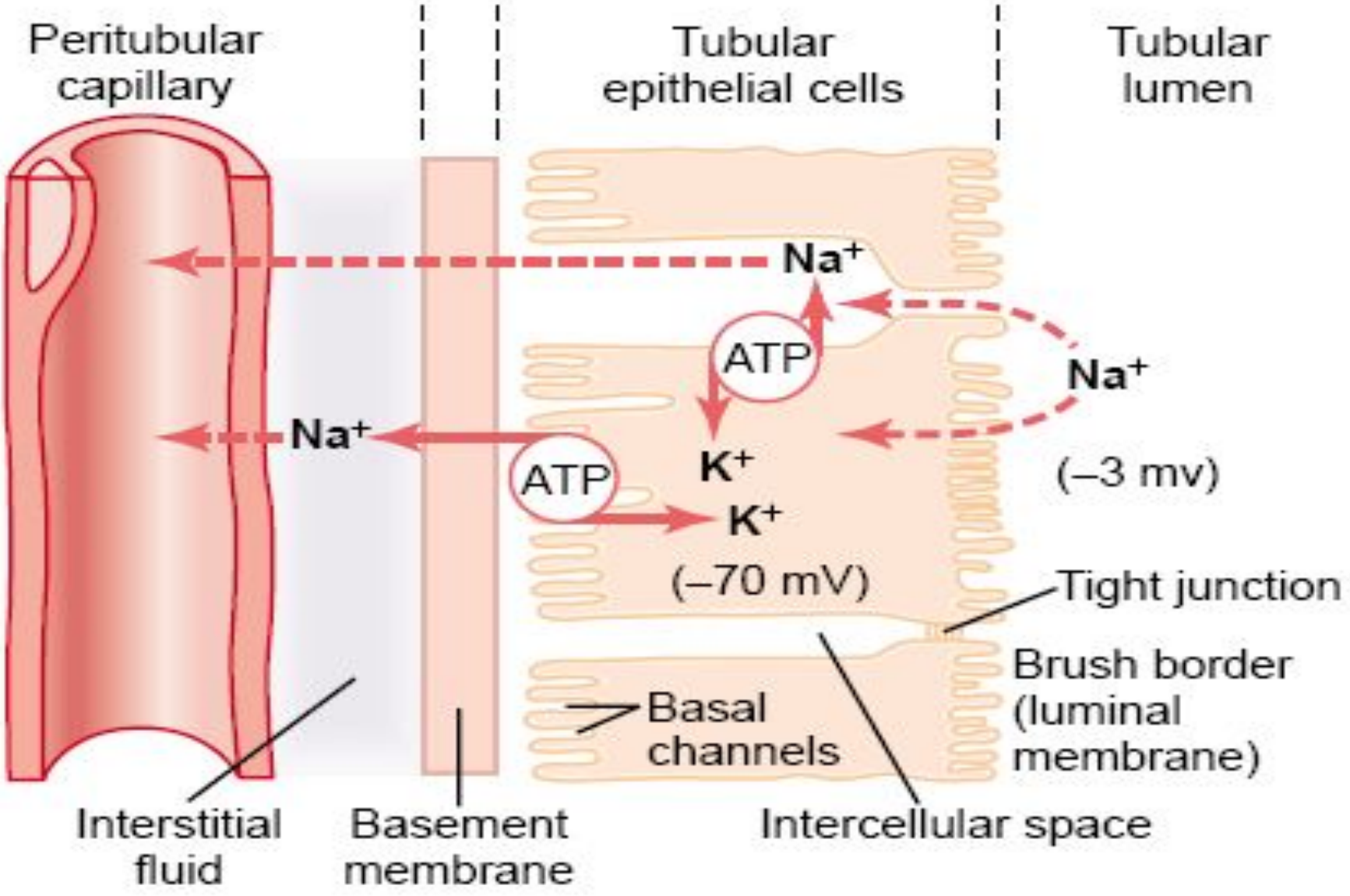
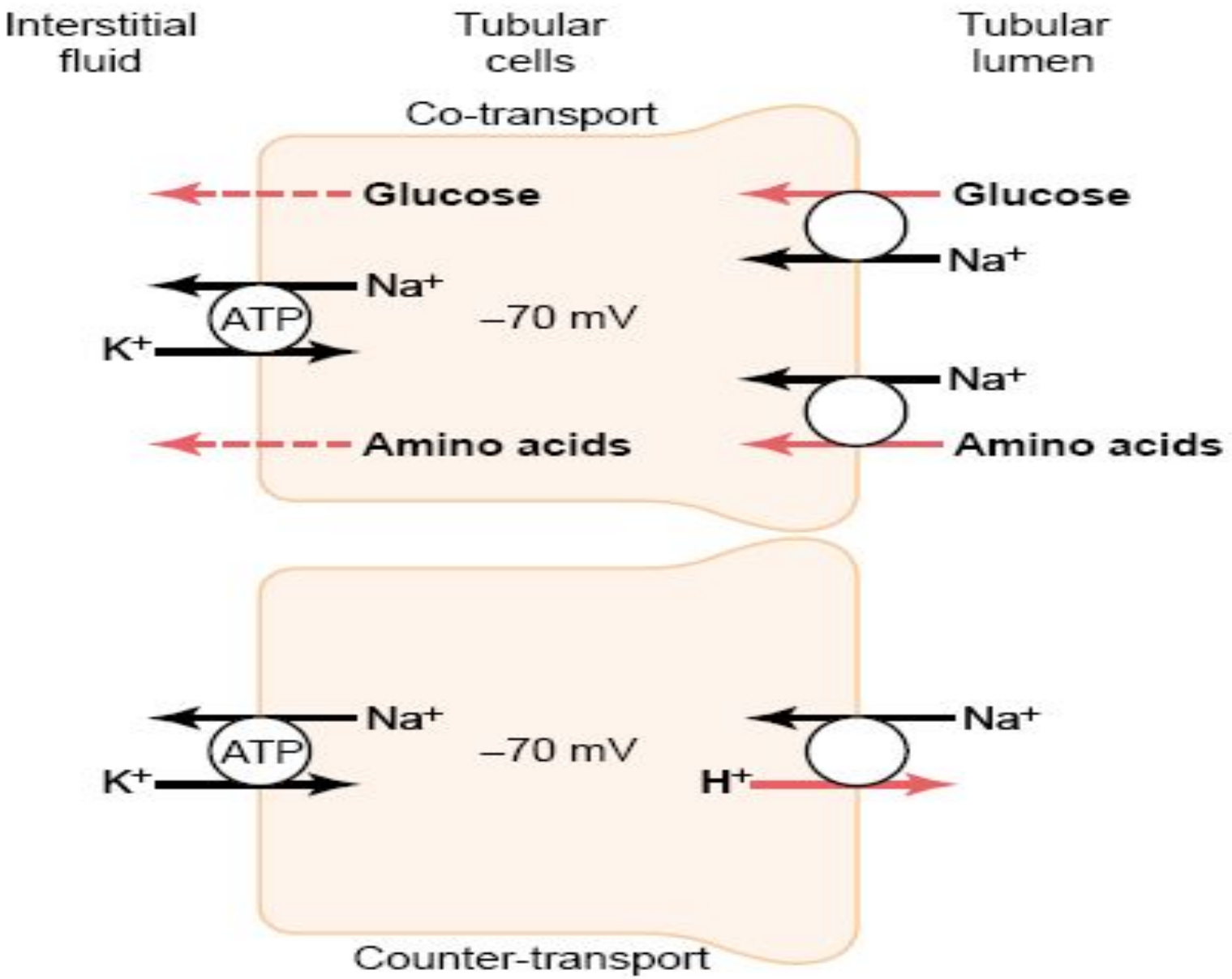



Peritubular capillary
Tubular epithelial cells
Tubular lumen
Na+
ATP
Na+
Na+
ATP
K+
(–3 mv)
K+
(–70 mV)
Tight junction
Brush border (luminal membrane)
Basal channels
Interstitial fluid
Basement membrane
Intercellular space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K+
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Na+
H+
Counter-transport

- **Effect of hormones-**
- **Angiotensin II** = Increase Nacl, H2O reabsorption, increase H+ secretion)
- **Parathyroid hormone =** Increase Ca++ reabsorption and decrease PO4 reabsorption.

Functions of PCT

(i) Normally, about **65% of the filtered load of Na+** (active transport) is reabsorbed by the PCT this leads **65% of H2O** (osmotically) **64% of filtered Cl** (electrically drag) and **50% of urea** to get reabsorbed as well.

(ii) **Glucose (100%), amino acids (100%),** lactate and Pi are reabsorbed by Na co transport.

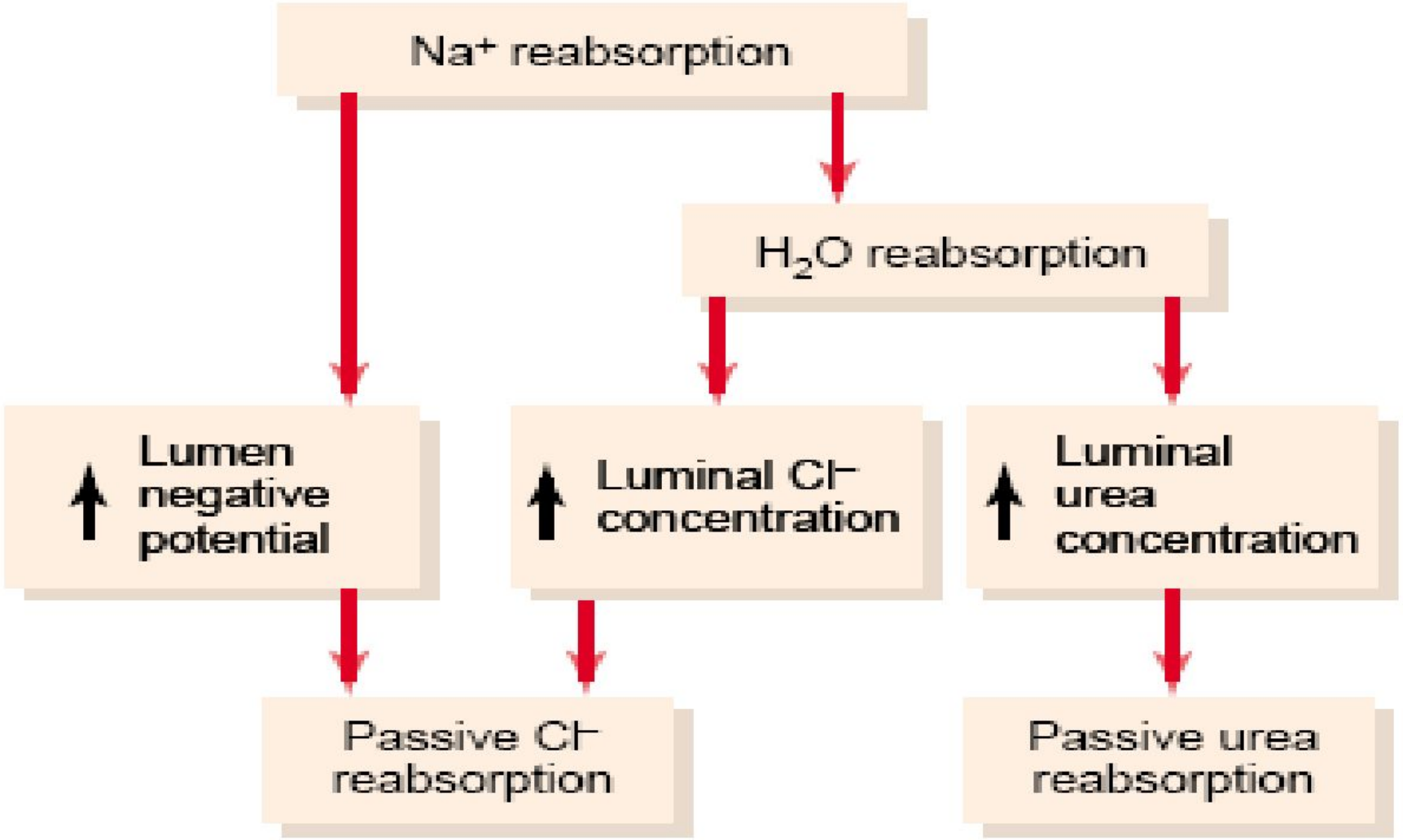
(iii) **85% of HCO3** (with H secretion by Na-H exchanger) is reabsorbed

(iv) About **65% of the filtered load of K** (active transport) is also reabsorbed.

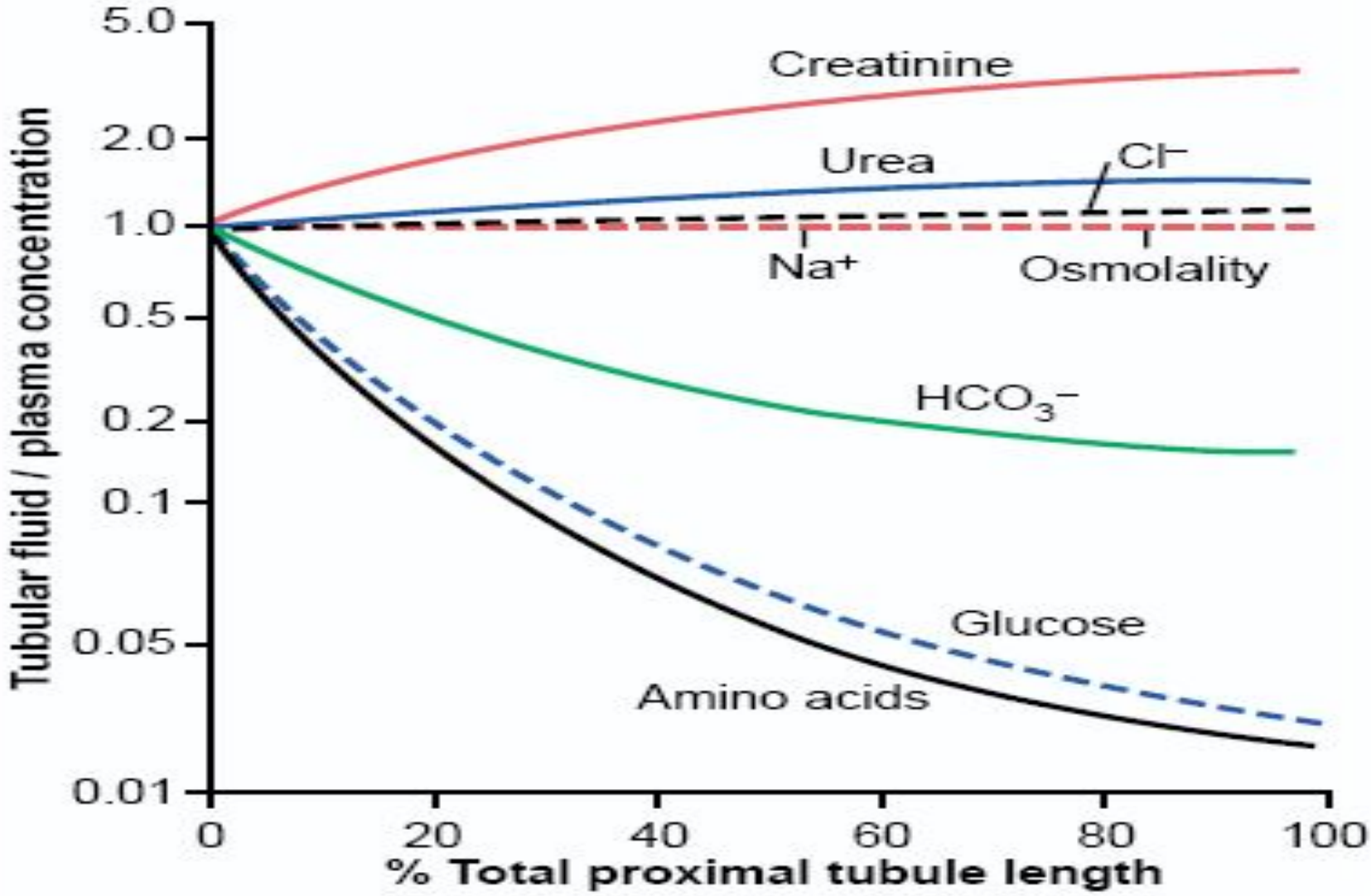
(v) The PCT is also an important site for **secretion of organic acids and bases** such as **bile salts, oxalate, urate, and catecholamine** as well as of **drugs** (like penicillin) and **dyes** (like PAH).

vi) Secretion of H+ ions.

- **Osmolarity change-** As both solutes and fluid are absorbed, fluid remains isosmotic (300 mOsm/L) in PCT.


Na+ reabsorption
H2O reabsorption
Lumen negative potential
Luminal Cl− concentration
Luminal urea concentration
Passive Cl− reabsorption
Passive urea reabsorption

Concentration of solutes



Functions of loop of Henle

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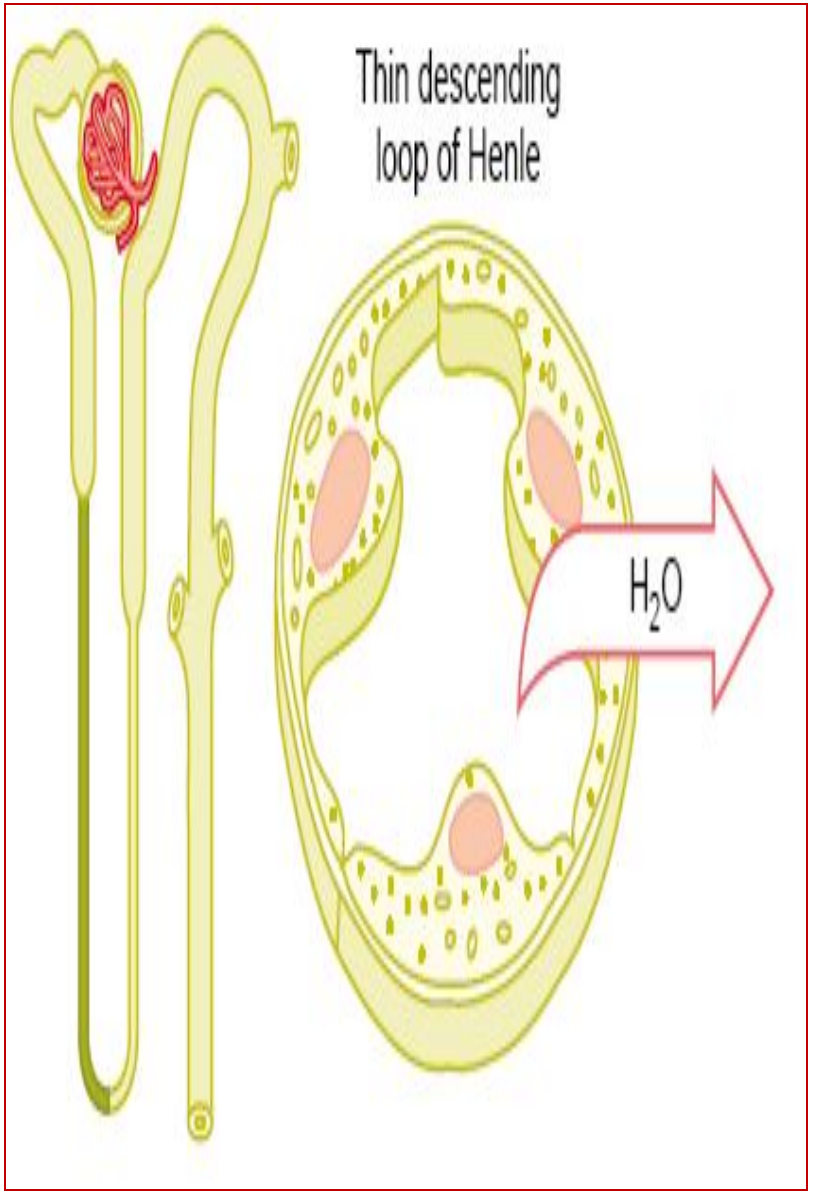

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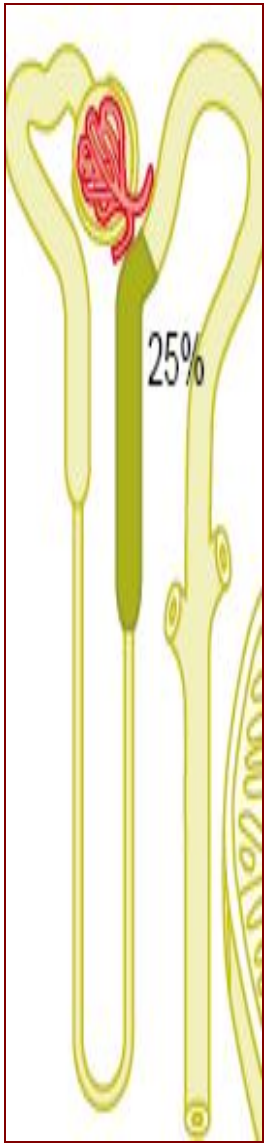

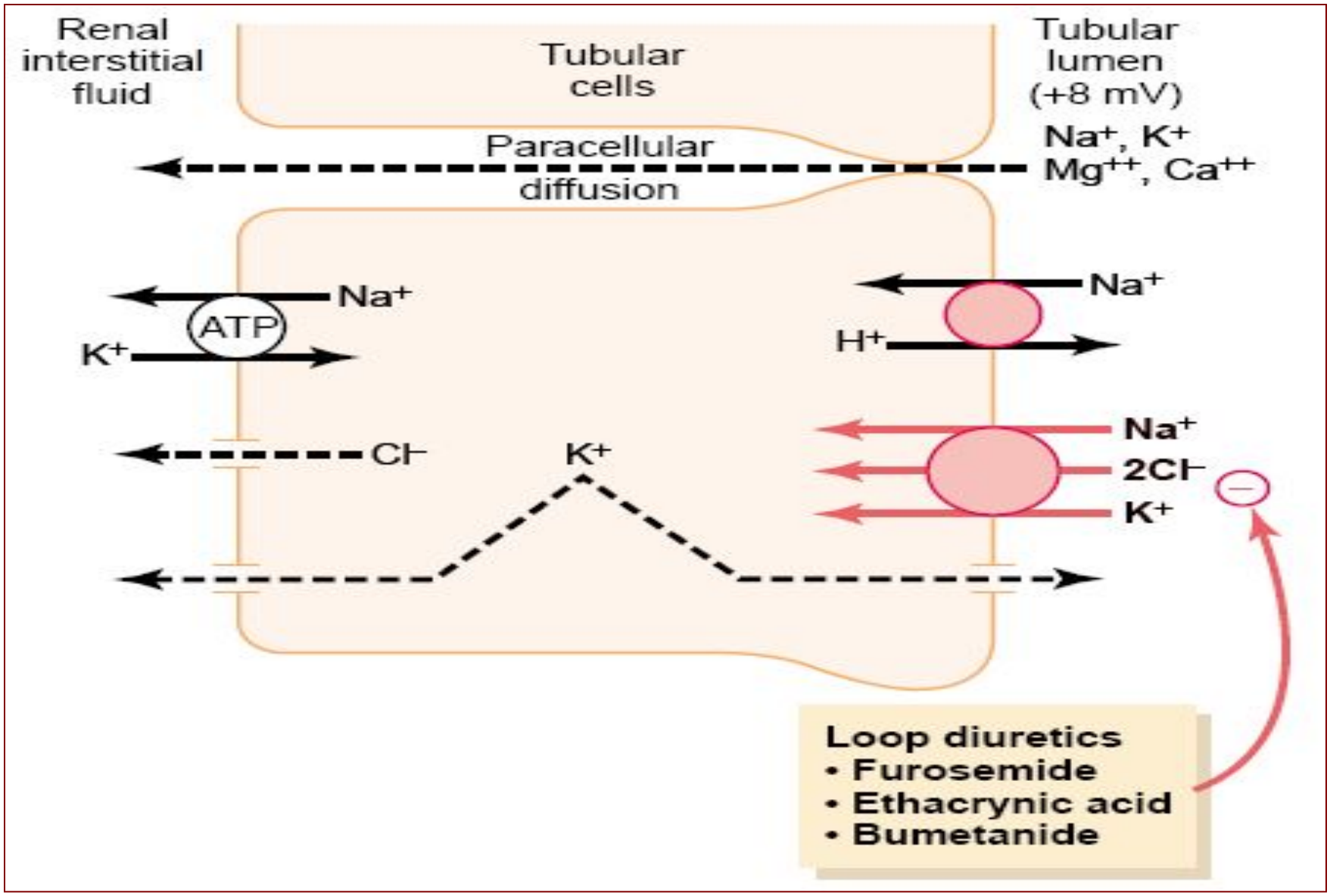
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Tubular lumen (+8 mV)
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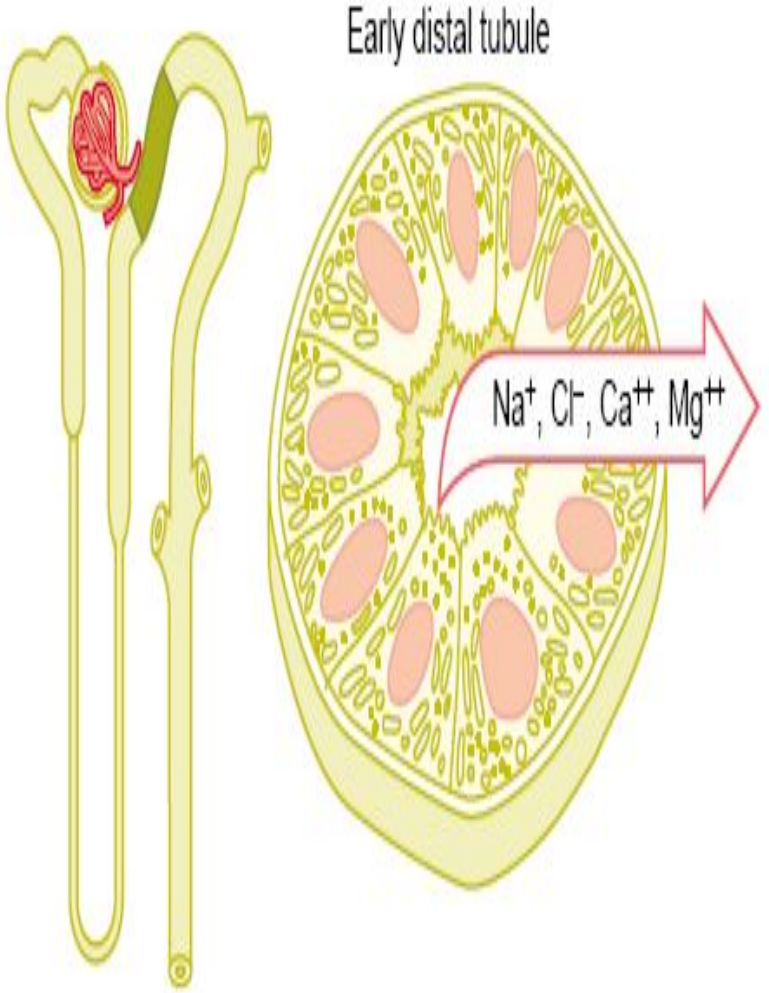

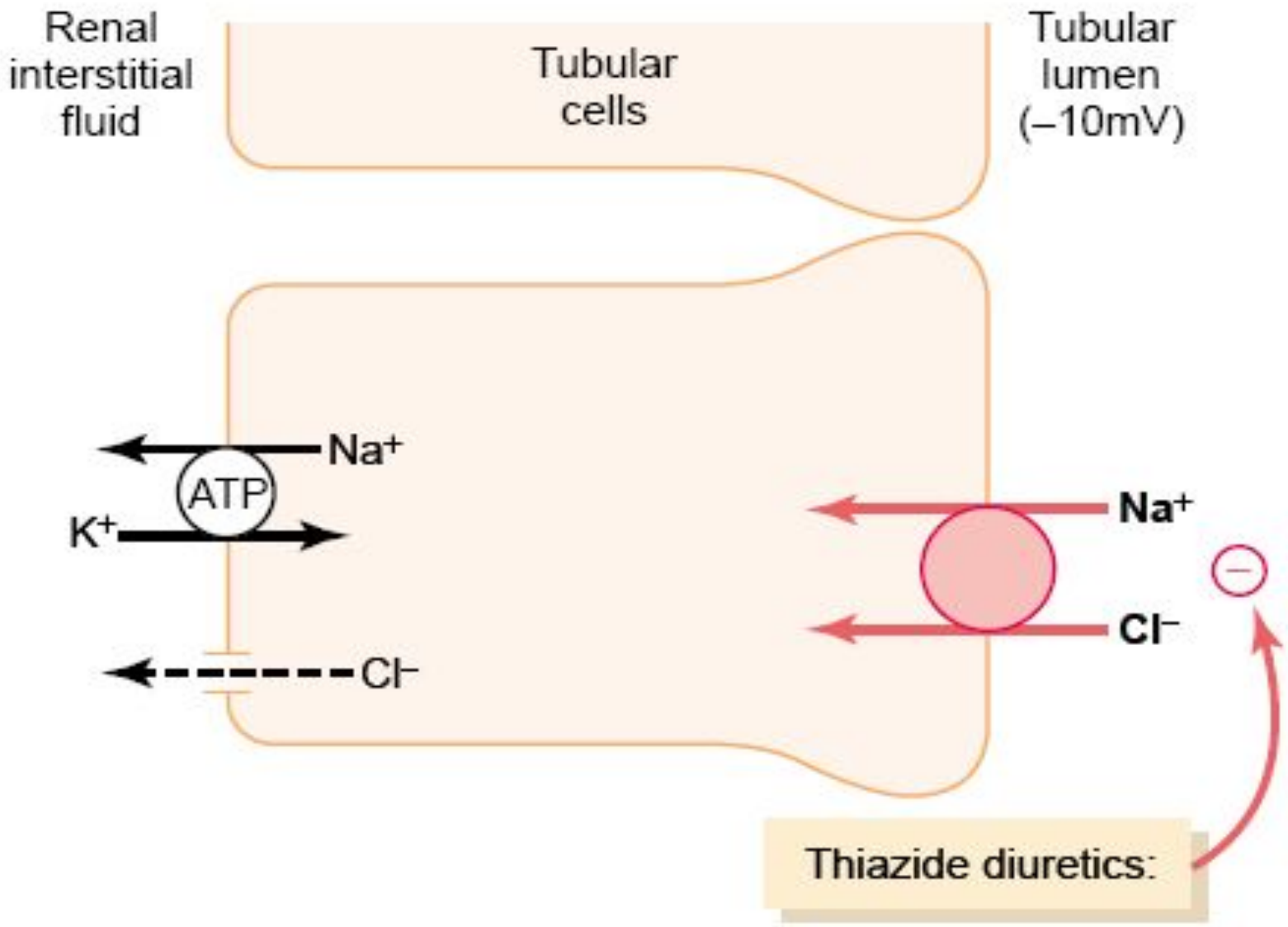
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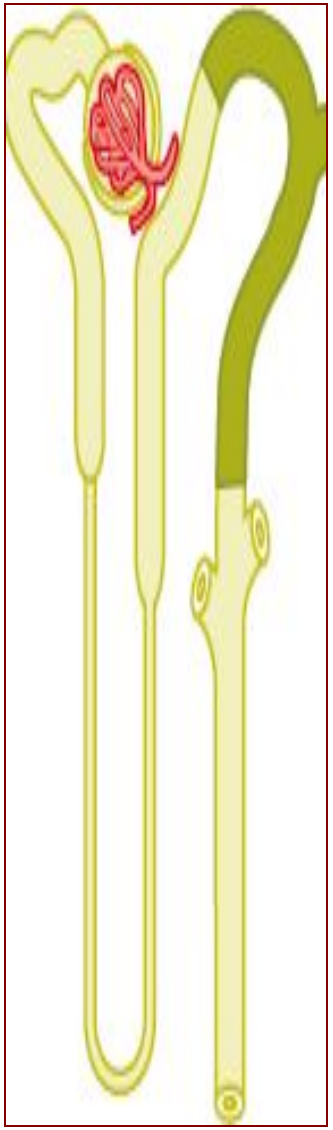

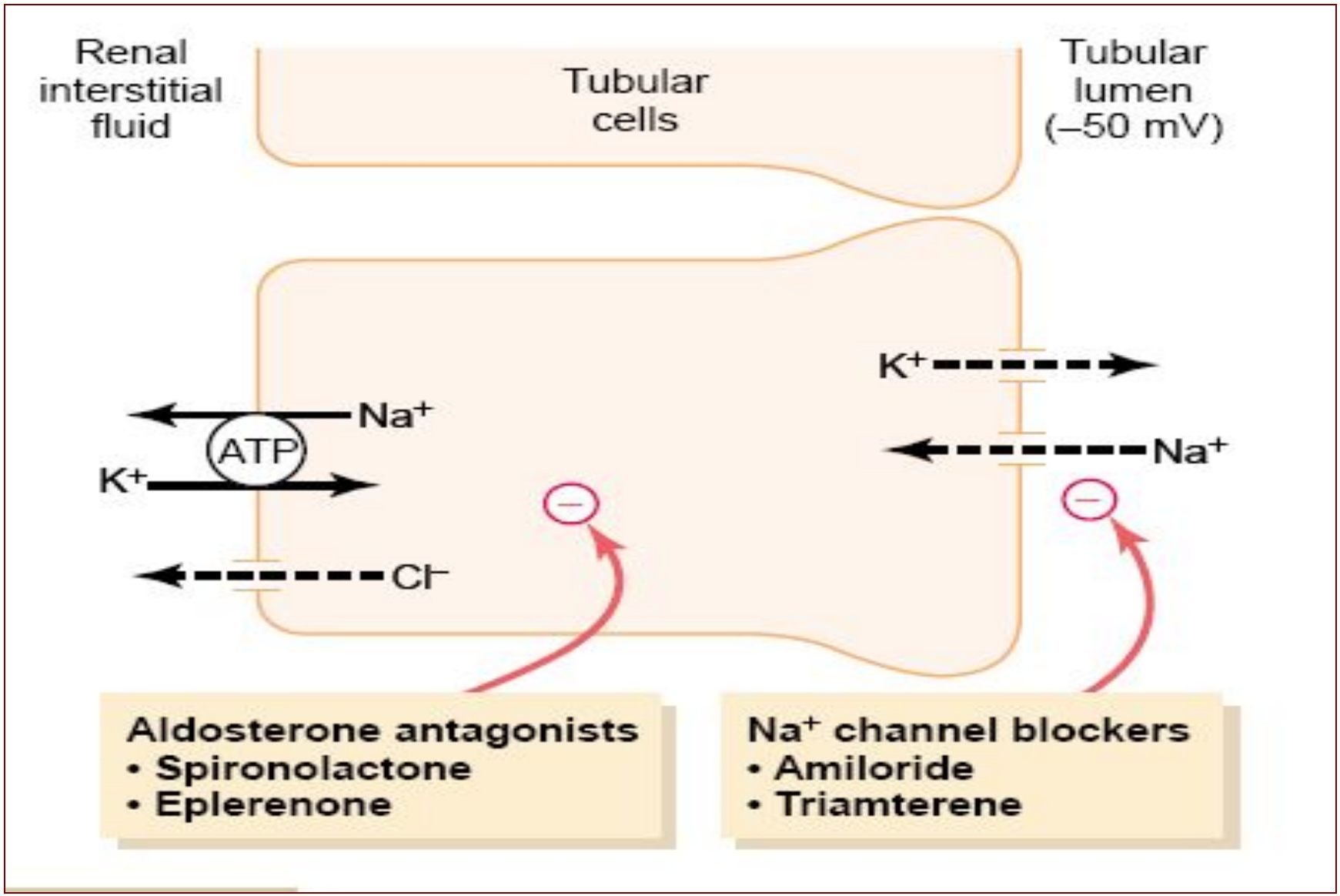
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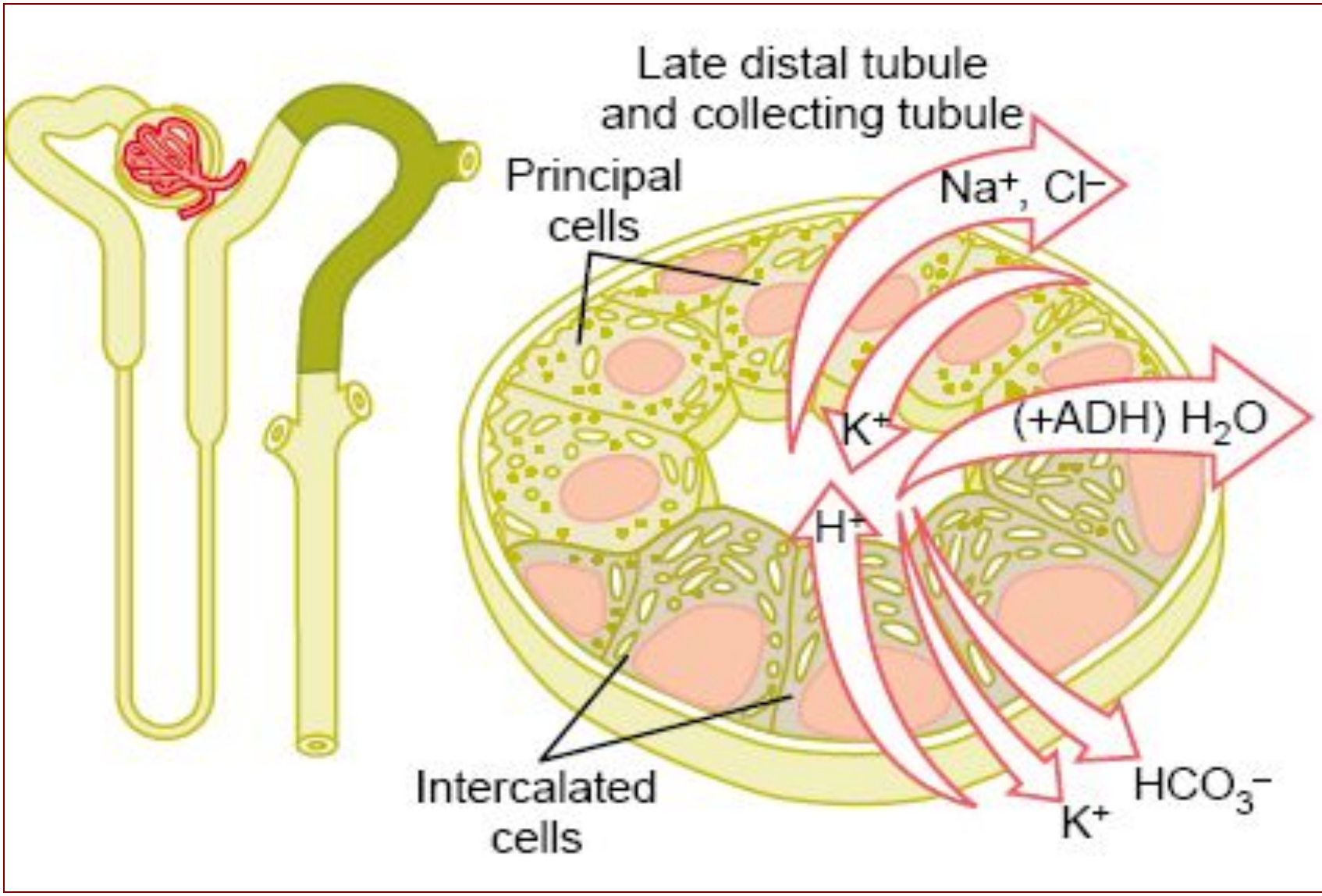
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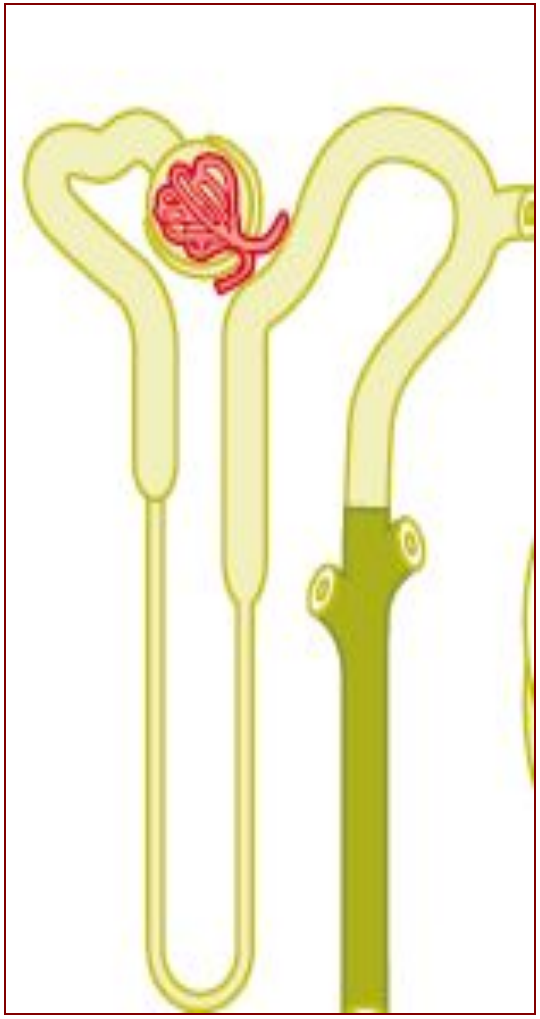
4. Under control of ADH ------
   - Permeable to water.



- In late DCT & CT osmolarity depends on the level of ADH.
- **With high level of ADH =**

i) DCT & CT --- highly permeable to water

ii) 99% water is reabsorbed.

iii) Osmolarity – 1200 -1400 mOsm/L.

iv) Formation of concentrated urine.

- **If ADH is absent**

i) DCT & CT ----- impermeable to water.

ii) 87 – 88% water is reabsorbed.

iii) Osmolarity ----- 50 mOsm/L

iv) Formation of diluted urine.

Functions-

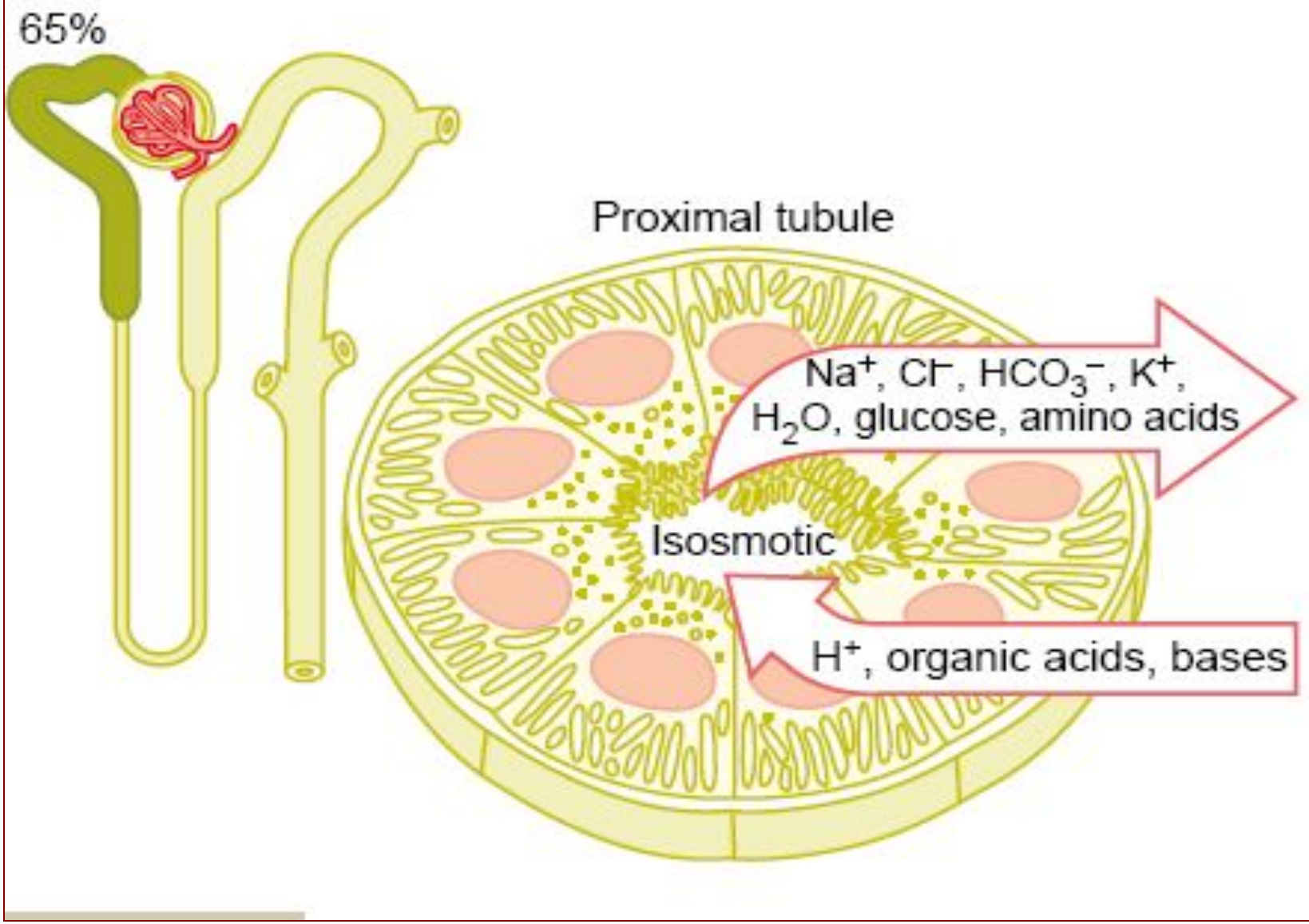
(i) The very first portion of the distal tubule forms part of **the juxtaglomerular complex** that provides feedback **control of GFR and blood flow.**

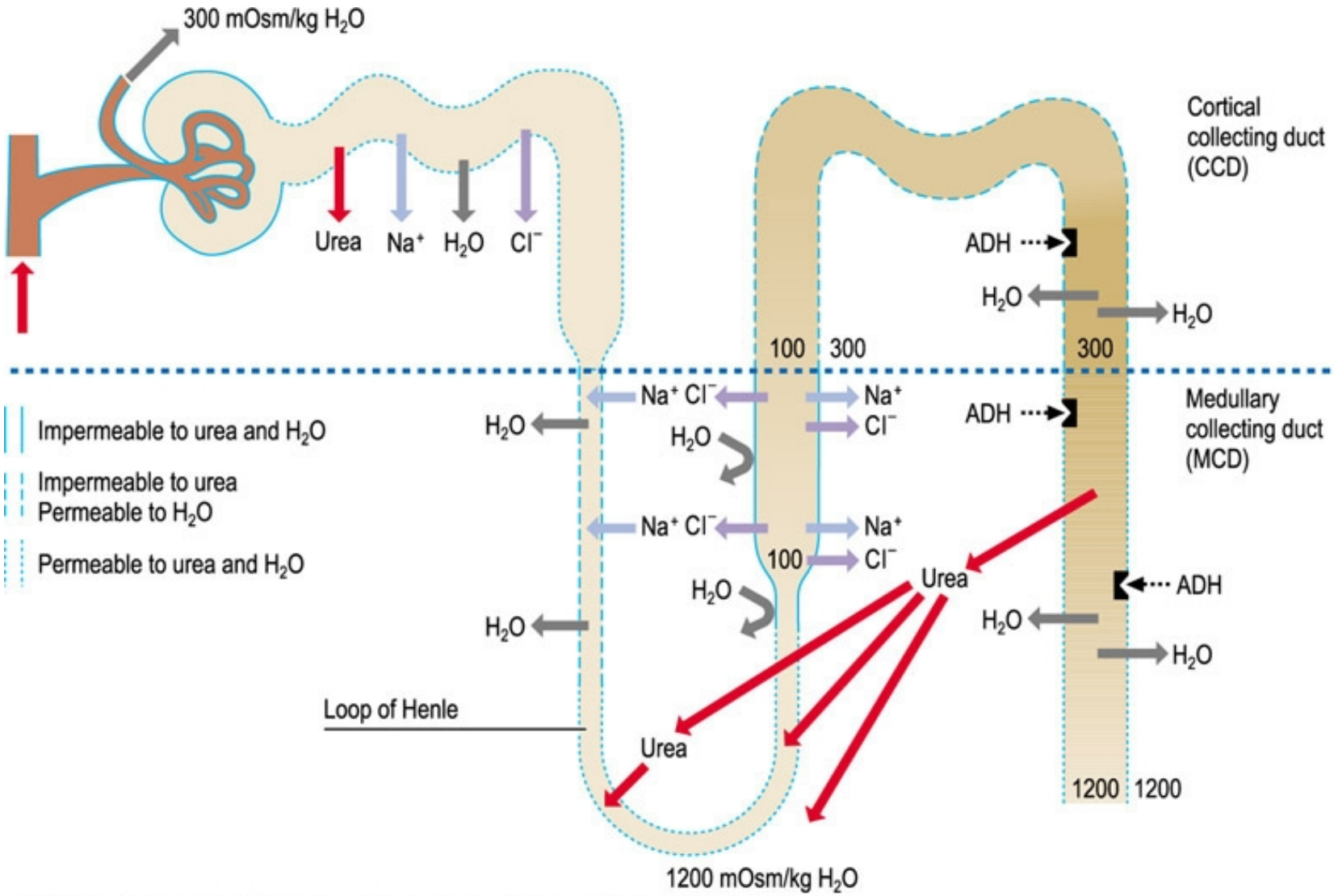
(ii) Approximately 5 % of the filtered load of sodium-chloride is reabsorbed in the early distal

iii) The P cells reabsorb sodium and water from the lumen and secrete potassium ions into the lumen. This activity depends on the activity of a sodium-potassium ATPase pump in each cell's basolateral membrane and is controlled by aldosterone. Thus P cells are important site for **regulation of body Na, blood volume, BP and plasma K level.**

(iv) The I cells secrete hydrogen ions by an active hydrogen-ATPase mechanism. Thus, the intercalated cells play a key role in **acid-base regulation** of the body fluids and **acidification of urine.**

v) DCT and cortical CT are almost completely impermeable to urea but the medullary CT is permeable to urea. Therefore, some of the tubular urea is reabsorbed into the medullary interstitium, helping to raise the osmolality in this region of the kidneys and contributing to the kidneys' overall ability to form **concentrated urine.**


65%
Proximal tubule
Na^+, Cl^-, HCO_3^-, K^+,
H_2O, glucose, amino acids
Isosmotic
H^+, organic acids, bases



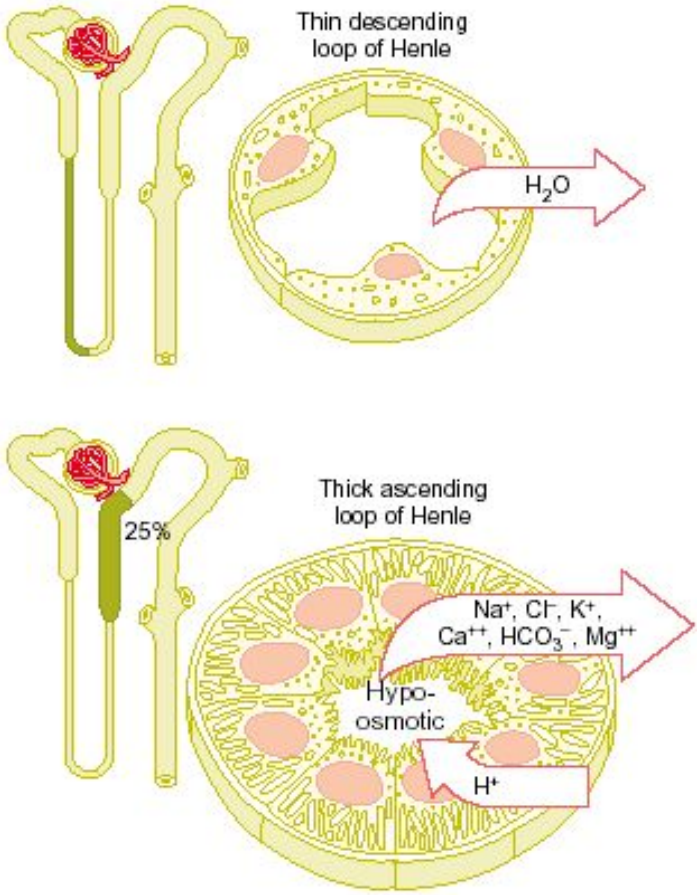
Loop of Henle

Thin segment

- Simple squamous epithelial cells
- Highly permeable to water but not to solutes
- Tubular fluid – hyper osmotic

Thick segment

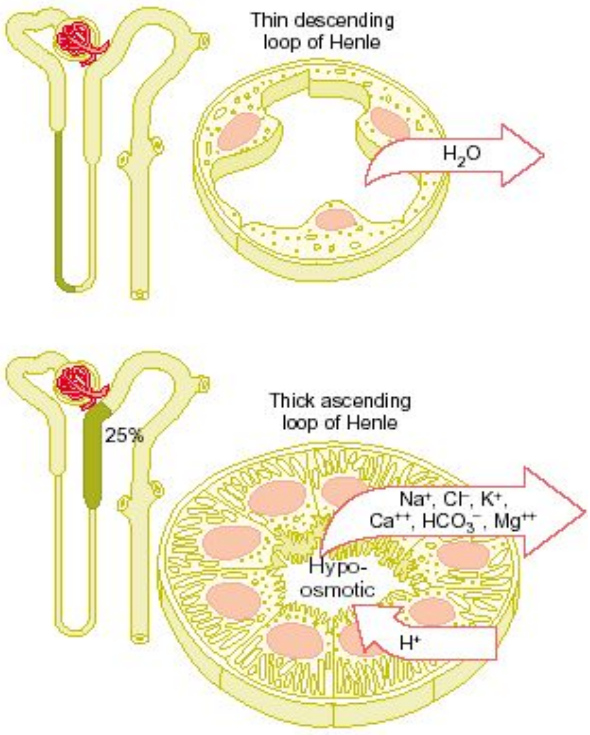
- Cuboidal epithellia
- Highly permeable to solutes – NaCl but not to water
- Tubular fluid – hypo osmotic



Loop of Henle

- Thin segment – simple diffusion of water
- Thick segment – active reabsorption of sodium, chloride and potassium are reabsorbed in the loop.25% of filtered load
- 1.sodium,2.chloride, 1.potassium co transporter

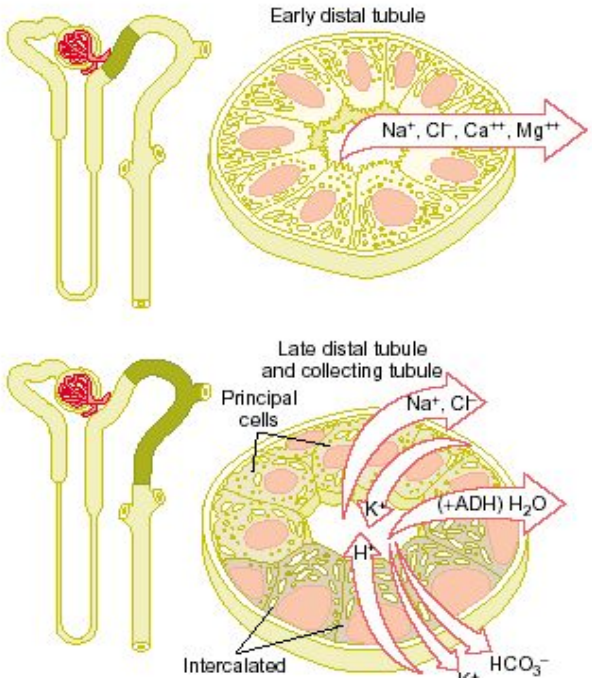
  calcium, bicarbonate, and magnesium are also reabsorbed in the thick ascending loop of Henle



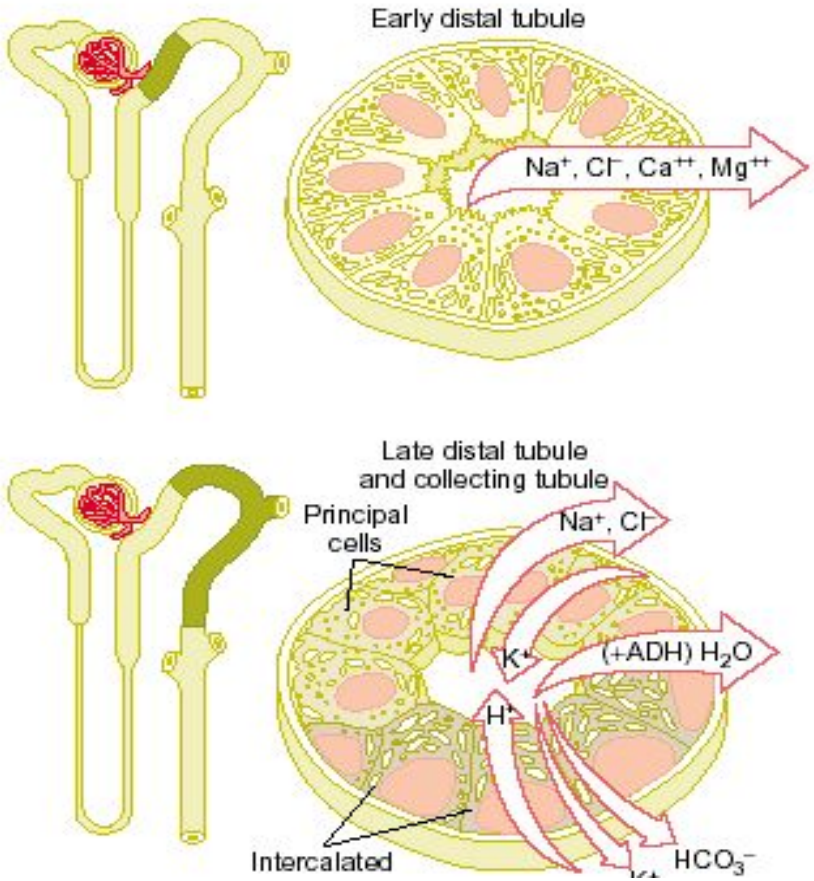
Distal tubules

- First portion – juxta glomerular complex

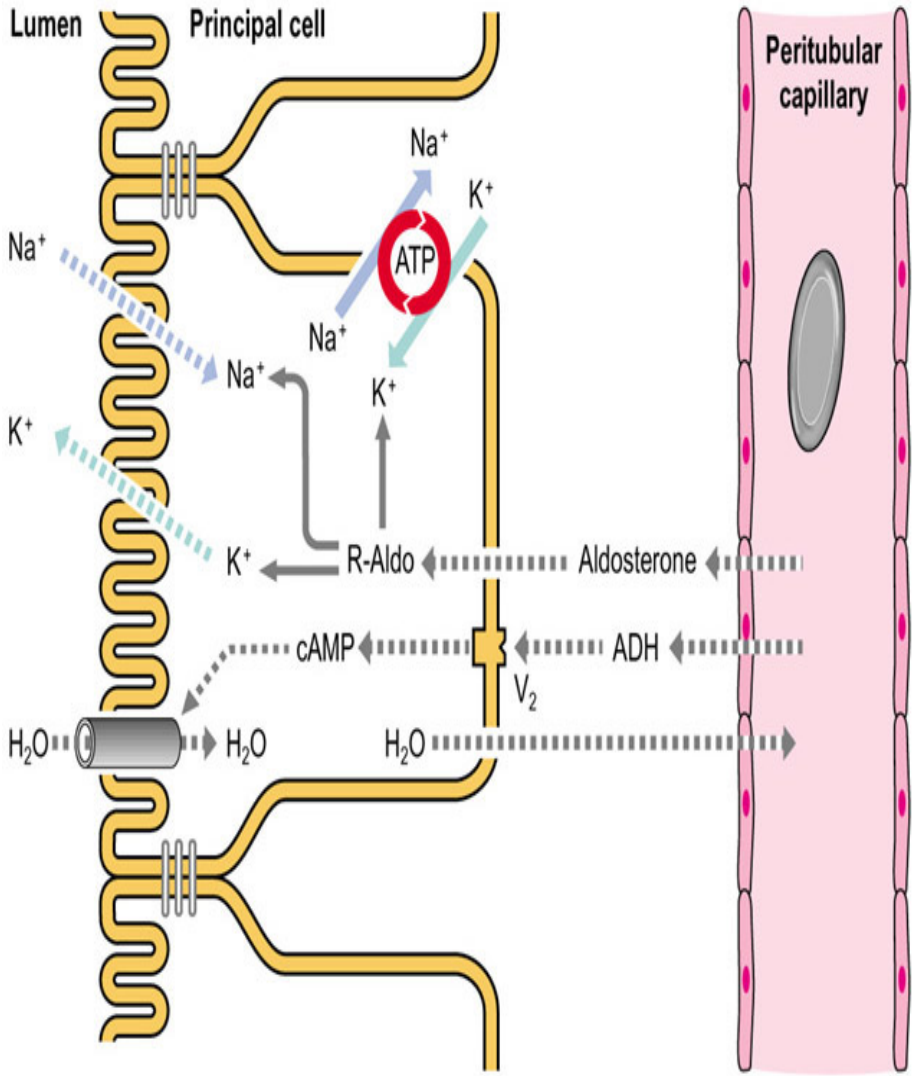
  provide feedback control of GFR and blood flow in this same nephron
- Second portion – like thick segment reabsorbs most of ions – Na, K, Cl but impermeable to water and urea
- Diluting segment



Late distal tubule &collecting tubule



- principal cells – permeability of water and solutes is regulated by hormones
- intercalated cells – regulate secretion of hydrogen ion for acid/base balancing



DCT and CT

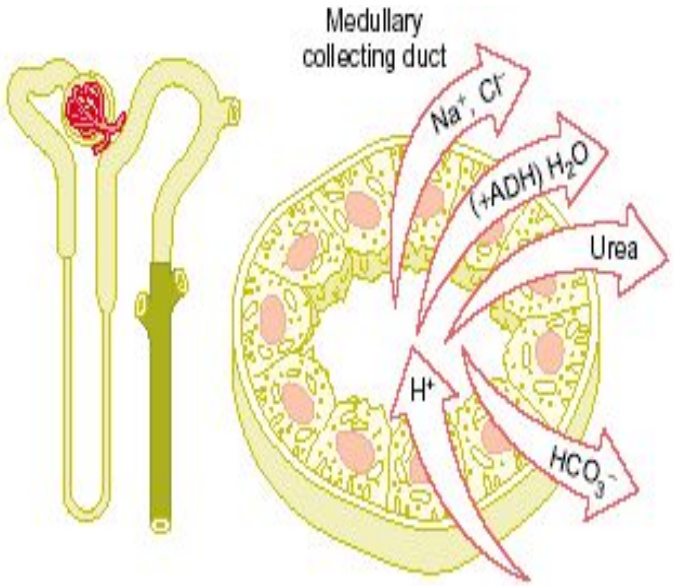
- Osmolarity change – depends on level of ADH
- Effect of hormones – aldosterone , ADH and ANP
- Clinical – thiazides diuretics – inhibit Na Cl cotransporter in early DCT

  aldosterone antagonist – spirinolectone – K retaining natriuretics

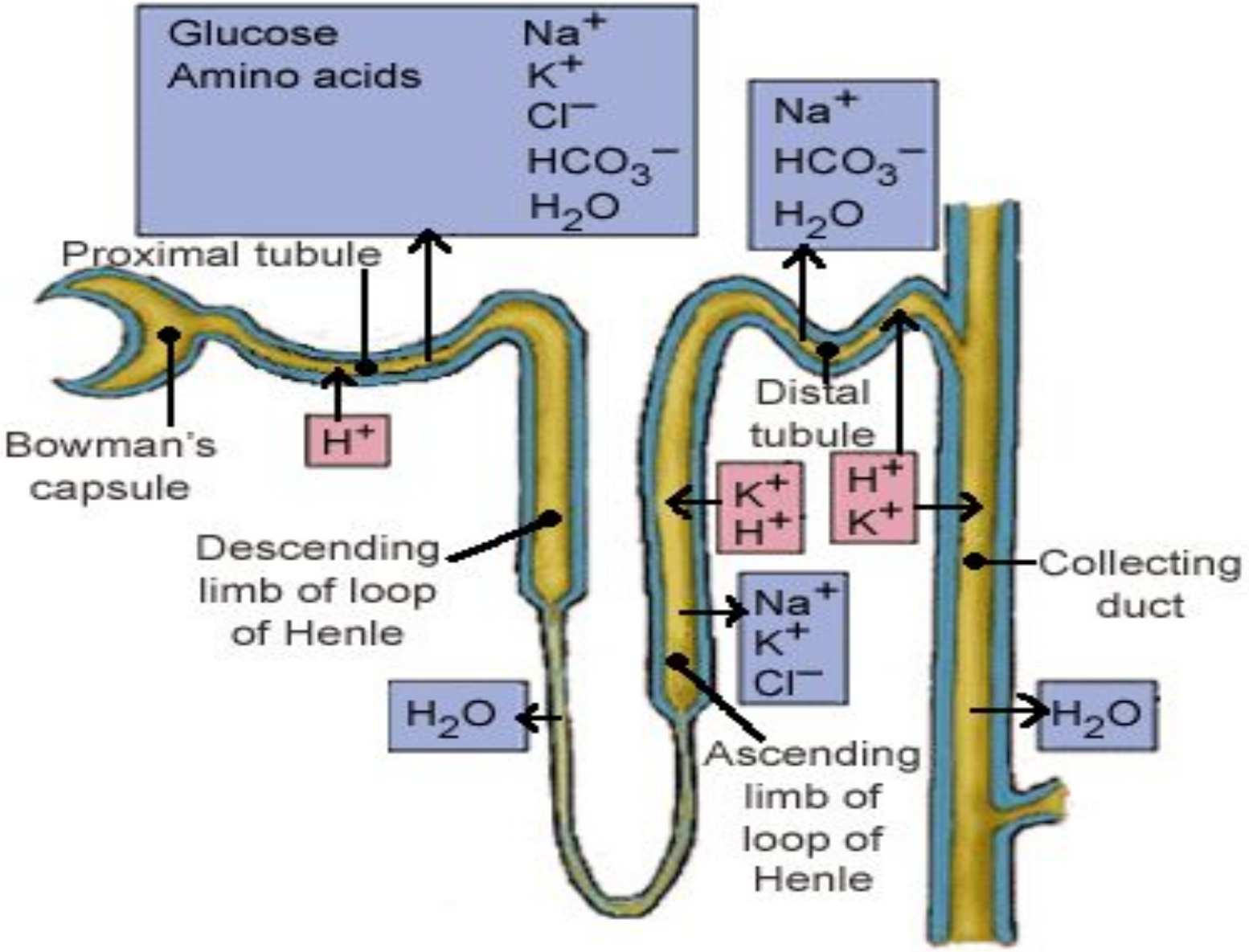
  Na channels blockers – triamterene , amiloride - acts on late DCT & CT

Medullary collecting duct

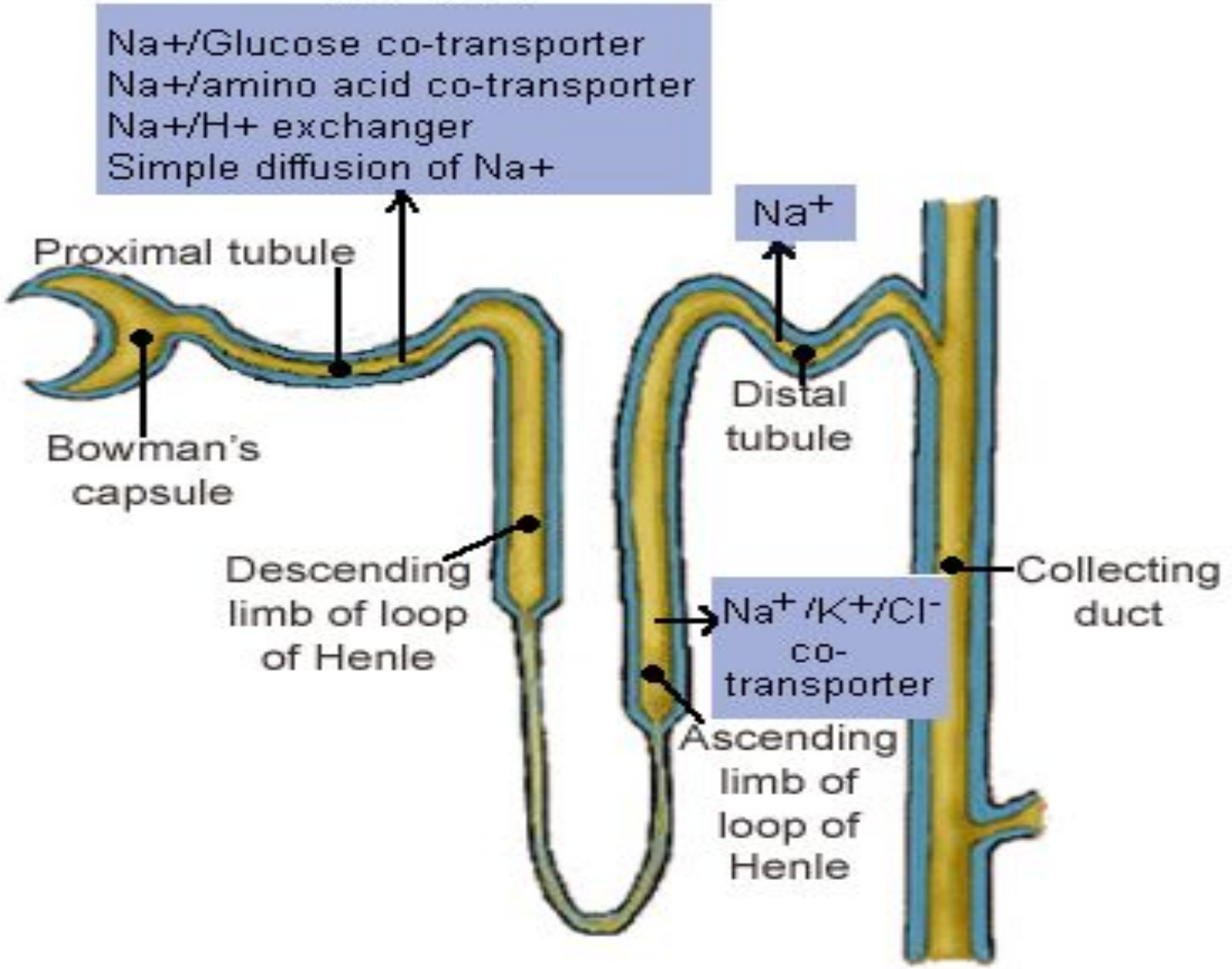
- The permeability of the medullary collecting duct to water is controlled by the level of ADH
- Concentrate urine by reabsorption of some of the tubular urea
- Capable of secreting hydrogen ions & plays key role in regulating acid base balance



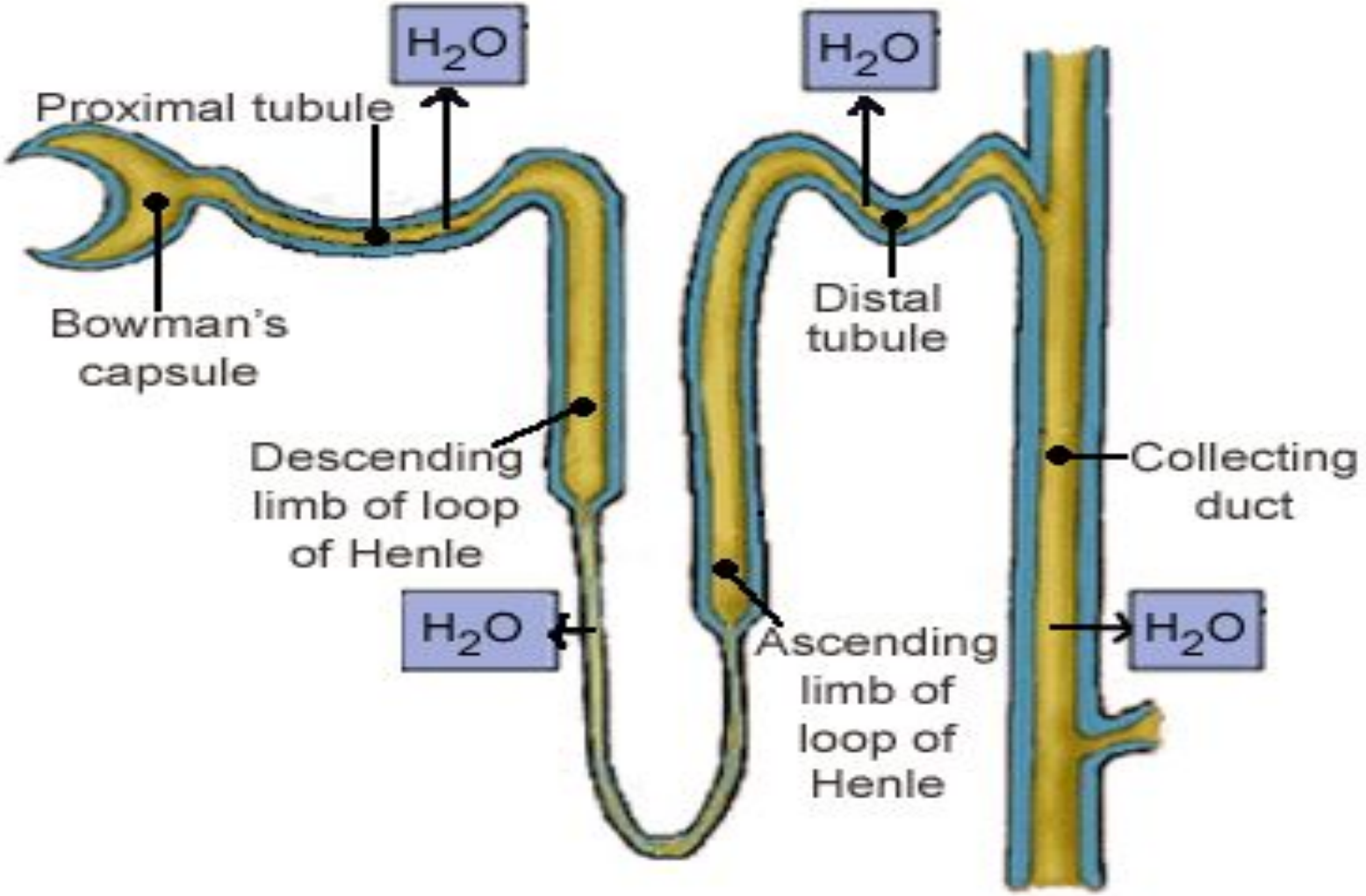
Tubular Reabsorption and Secretion



Tubular Reabsorption of Na^+



Tubular Reabsorption of Water



Tubular Reabsorption and Secretion of K^+ and Cl^-