Tubular Functions

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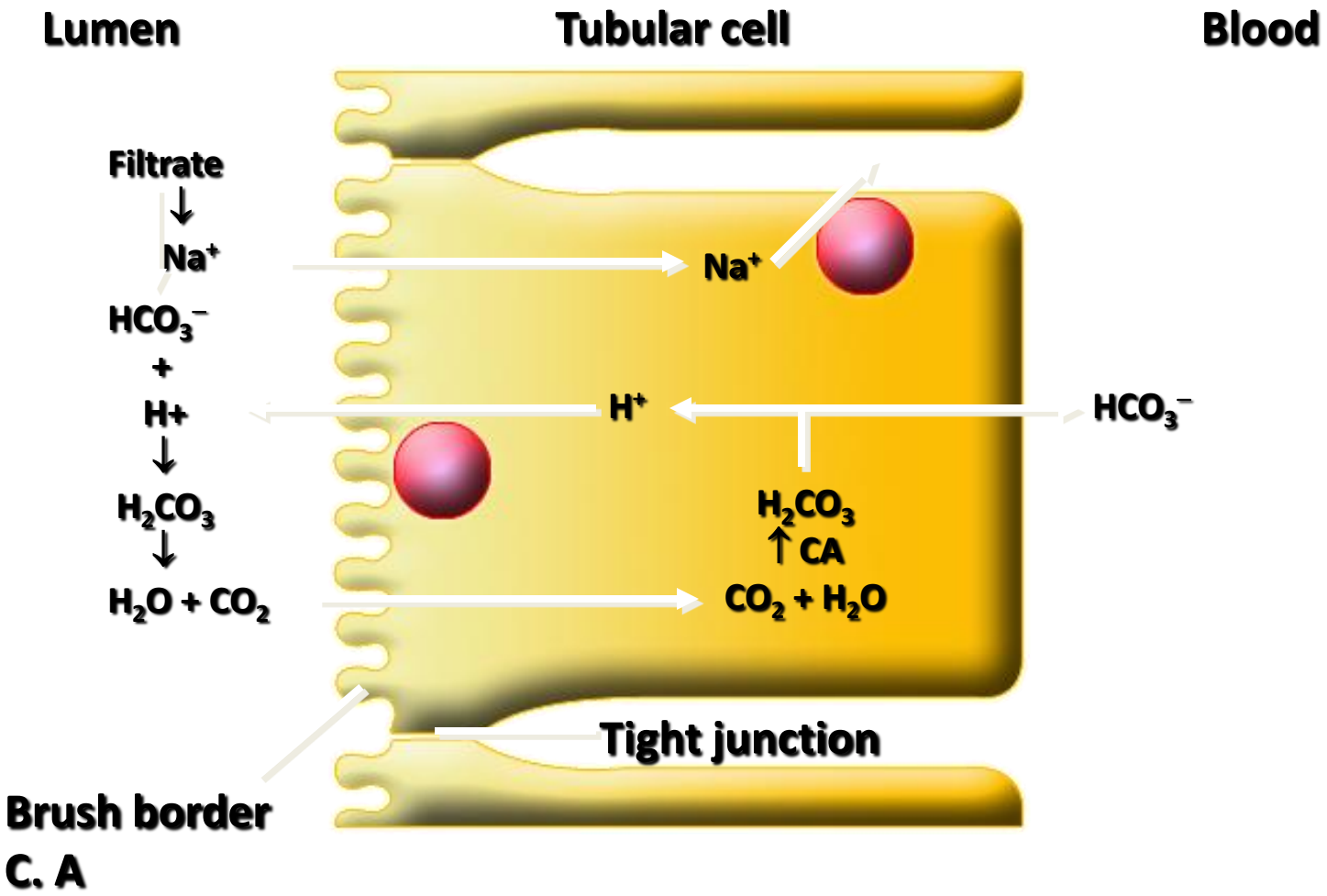
Objectives

At the end of this lecture student should be able to describe:

1. **Mechanism of Bicarbonate reabsorption**
2. **Mechanism of Phosphate reabsorption**
3. **Urea reabsorption**
4. **Mechanism of Tubular secretion of K & H**

Bicarbonate reabsorption *cont.*



Bicarbonate reabsorption

- 90% of filtered is reabsorbed in PCT
- Filtered $HCO_3 + H^+ \rightarrow H_2CO_3$
- $H_2CO_3 \rightarrow H_2O + CO_2$ in the presence of carbonic anhydrase enzyme
- CO_2 diffuses into the cell + $H_2O \rightarrow H_2CO_3$
- $H_2CO_3 \rightarrow H^+ + HCO_3$
- HCO_3 is reabsorped by simple diffusion
- H^+ is secreted in exchange for Na^+

Phosphate reabsorption

- **Bones, teeth & skeleton = 80%**
- **Intracellular P =20%**
- **Plasma P= 1mmol/L freely filtered**
- **1/3 of filtered P is excreted in urine**
- **2/3 Reabsorbed cotransported with Na**
- **Rate of absorption is under the control of PTH & VD**

Urea reabsorption

- **Plasma urea concentration =15-40mg /100ml**
- **End product of protein metabolism**
- **40-50% of filtered urea reabsorbed**
  - **Reabsorbed by Passive diffusion following Na and water**
- **50-60% excreted**

Urea reabsorption

- **↓GFR (renal disease; low renal blood flow) →↑urea concentration in plasma due:**
  - **Reduction in urea filtration**
  - **more urea reabsorbed to blood due to slow flow rate of filtrate**

Tubular secretion

- **From peritubular blood through peritubular space into renal tubular cell to tubular lumen**
- **Secretion:**
  - **Passive NH3, salicylic acid**
  - **Active**
    - **Tubular maximum (Tm): creatinine; PAH**
    - **No Tm: K; H**

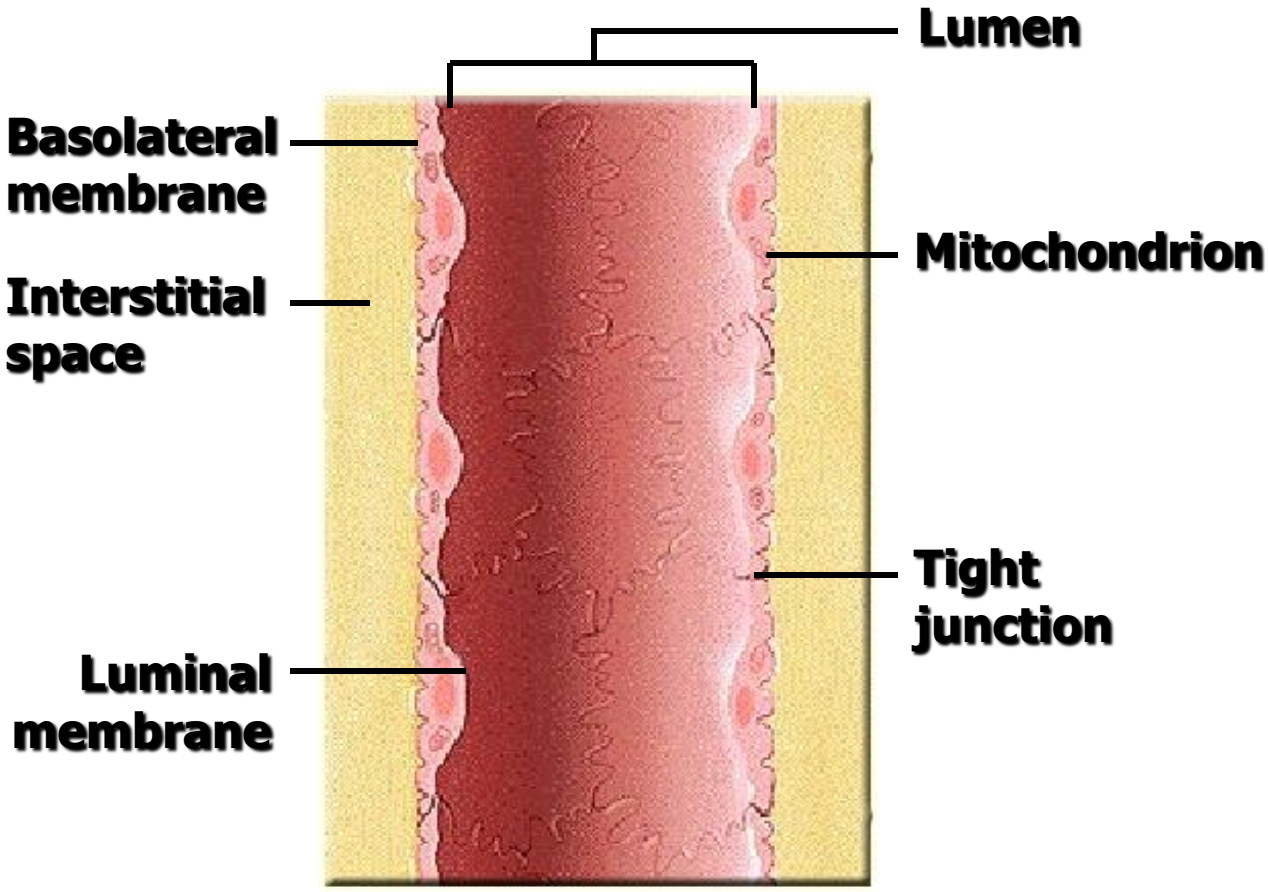
Tubular secretion *cont.*

- **Potassium**
  - **90% of filtered K is reabsorbed (PCT)**
  - **K is secreted in DCT in exchange for Na and under the control of Aldosterone hormone**
- **Hydrogen**
  - **Excretion exchange for Na**

Loop of Henle

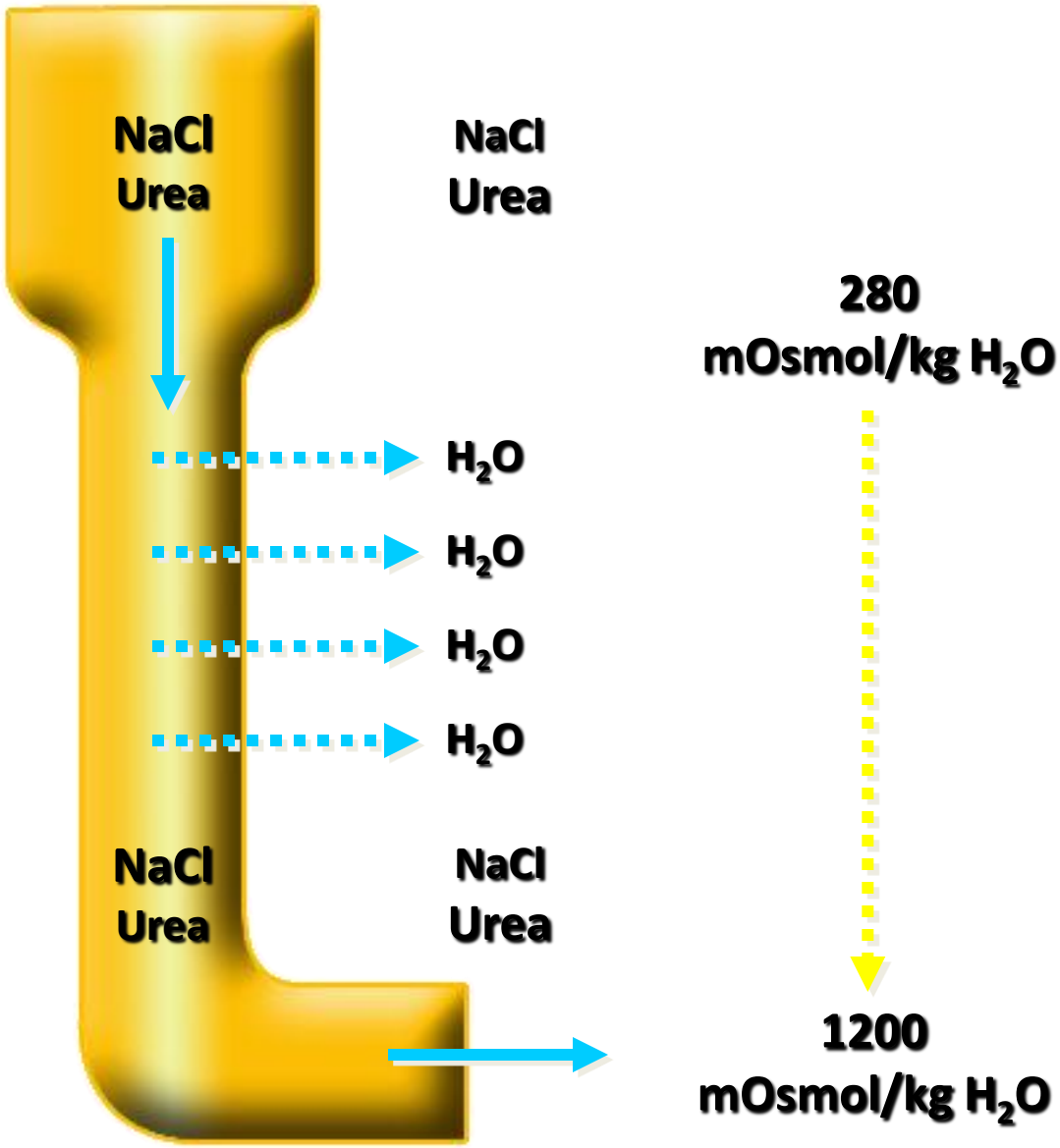
The Thin Loop of Henle

Cells simple squamous epithelial cells. Highly permeable to water but not to solutes



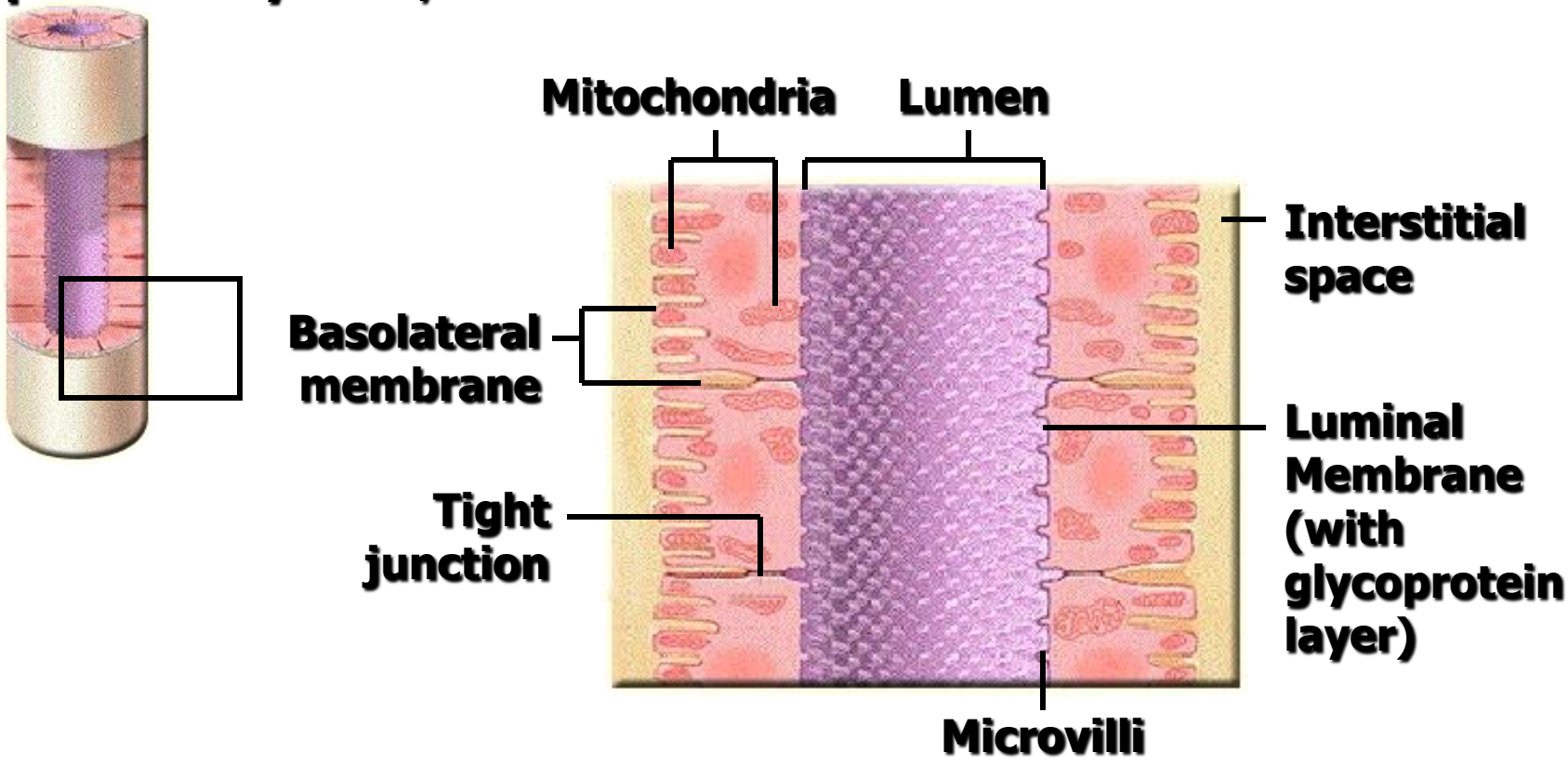
The descending Loop

- **Permeable to water but not for solute absorption**
- **20% of filtered water is reabsorbed**
- **osmolality of filtrate increases from 290 to 1200 mOsm/l at the tip of the loop**
- **The increasing osmolality is due to only water reabsorption, ↑ NaCl and ↑Urea concentration in filtrate**


NaCl
Urea
NaCl
Urea
H2O
H2O
H2O
H2O
NaCl
Urea
NaCl
Urea
280
mOsmol/kg H2O
1200
mOsmol/kg H2O

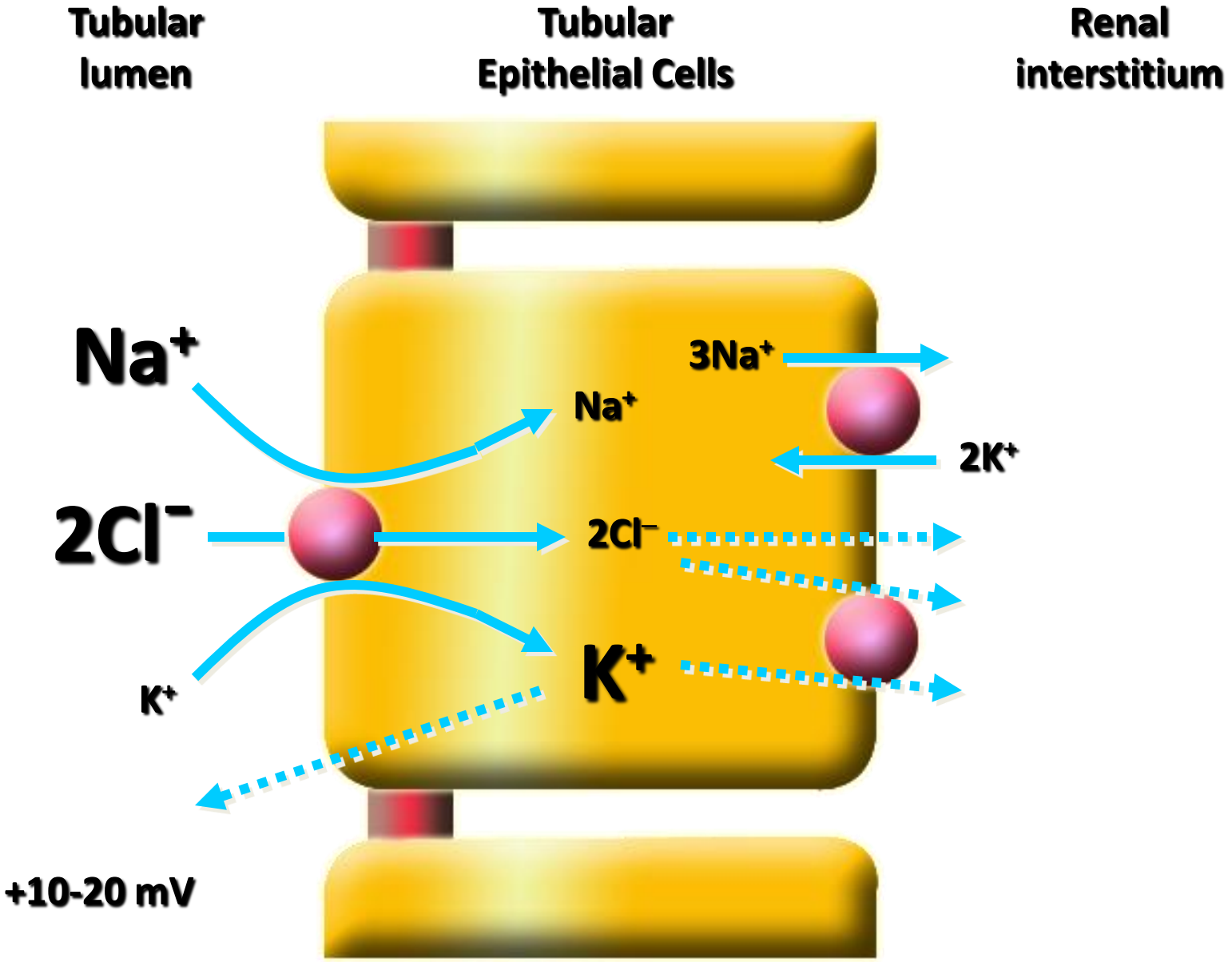
The Ascending Loop of Henle and Early DCT

Cells are cuboidal epithelia; Highly permeable to solutes, particularly NaCl, but not to water



The Ascending limb

- 1/3 Thin ?
- 2/3 Thick
  - Water imperable
  - Na/K/2Cl reabsorption by cotransport (luminar)
  - Na/K ATPase in basolateral membrane
- Filtrate diluted due to solute reabsorption not water
- Osmolarity drop from 1200 to 200mosm/l

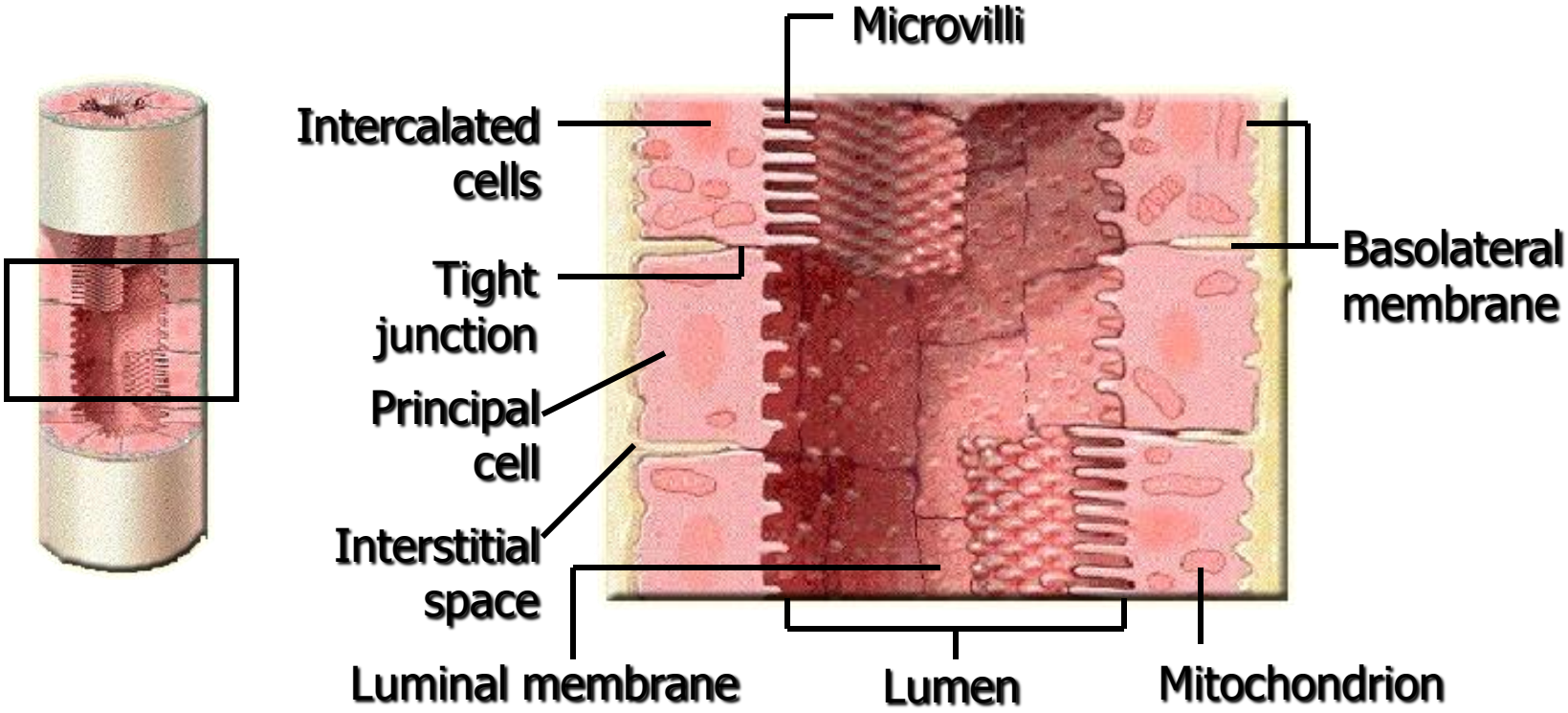

Tubular lumen
Tubular Epithelial Cells
Renal interstitium
Na+
2Cl−
K+
+10-20 mV
Na+
2Cl−
K+
3Na+
2K+

Thick ascending Loop

- **The thick ascending limb is very sensitive to diuretic drugs (Furosamide). These diuretics block Na+-K+-2Cl$^-$ cotransporter:**
  - **Decreased NaCl reabsorption**
  - **Isotonic fluid delivered to distal tubule instead of a hypotonic fluid**
  - **Increased fluid excretion – "diuresis"**
  - **These drugs are called "Loop" diuretics**

The Late DCT and Cortical Collecting Duct

Cuboidal cells are of two distinct functional types principal and intercalated cells.



- Principal cells permeability to water and solutes is regulated by hormones
- Intercalated cells secretion of hydrogen ions for acid/base balancing

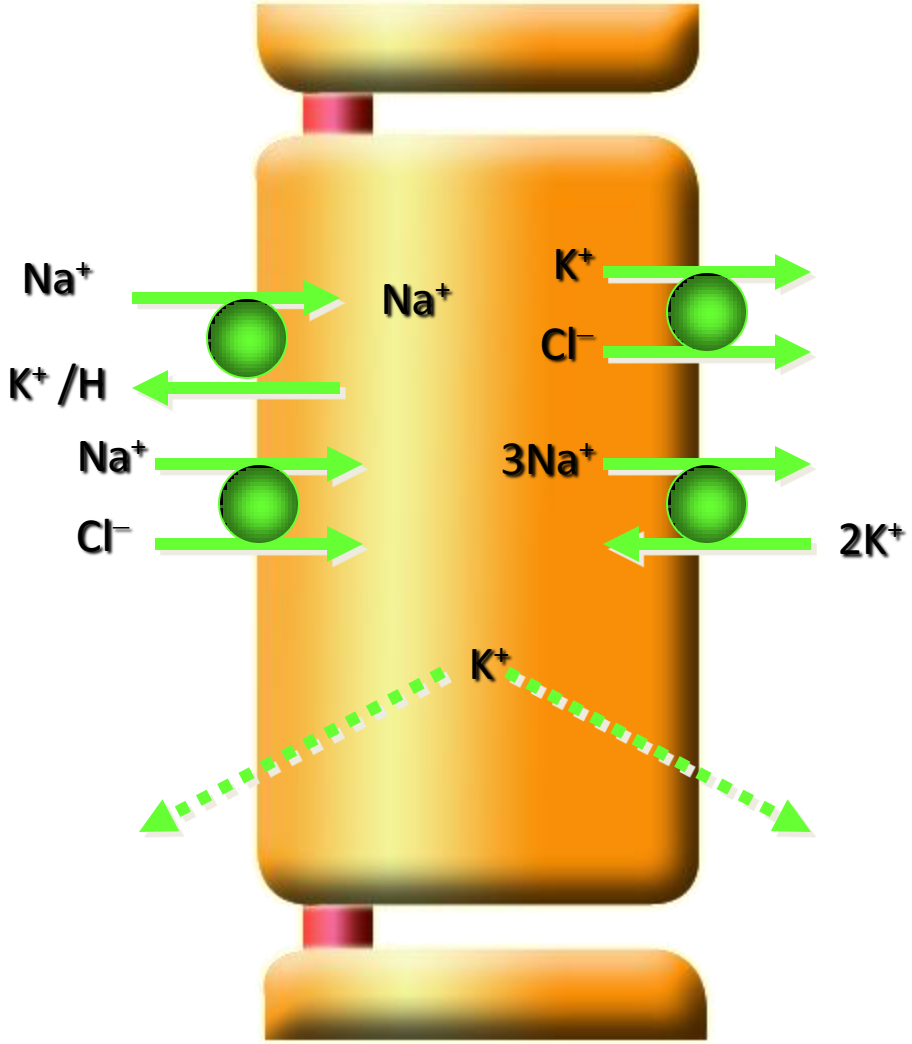
The Late DCT and Cortical Collecting Duct

- **19% of filtered H_2O is reabsorbed**
- **9% of filtered Na^+ is reabsorbed in exchange of K^+ or H^+**
- **Cl^- also reabsorbed**

Tubular lumen

Tubular Epithelial Cells

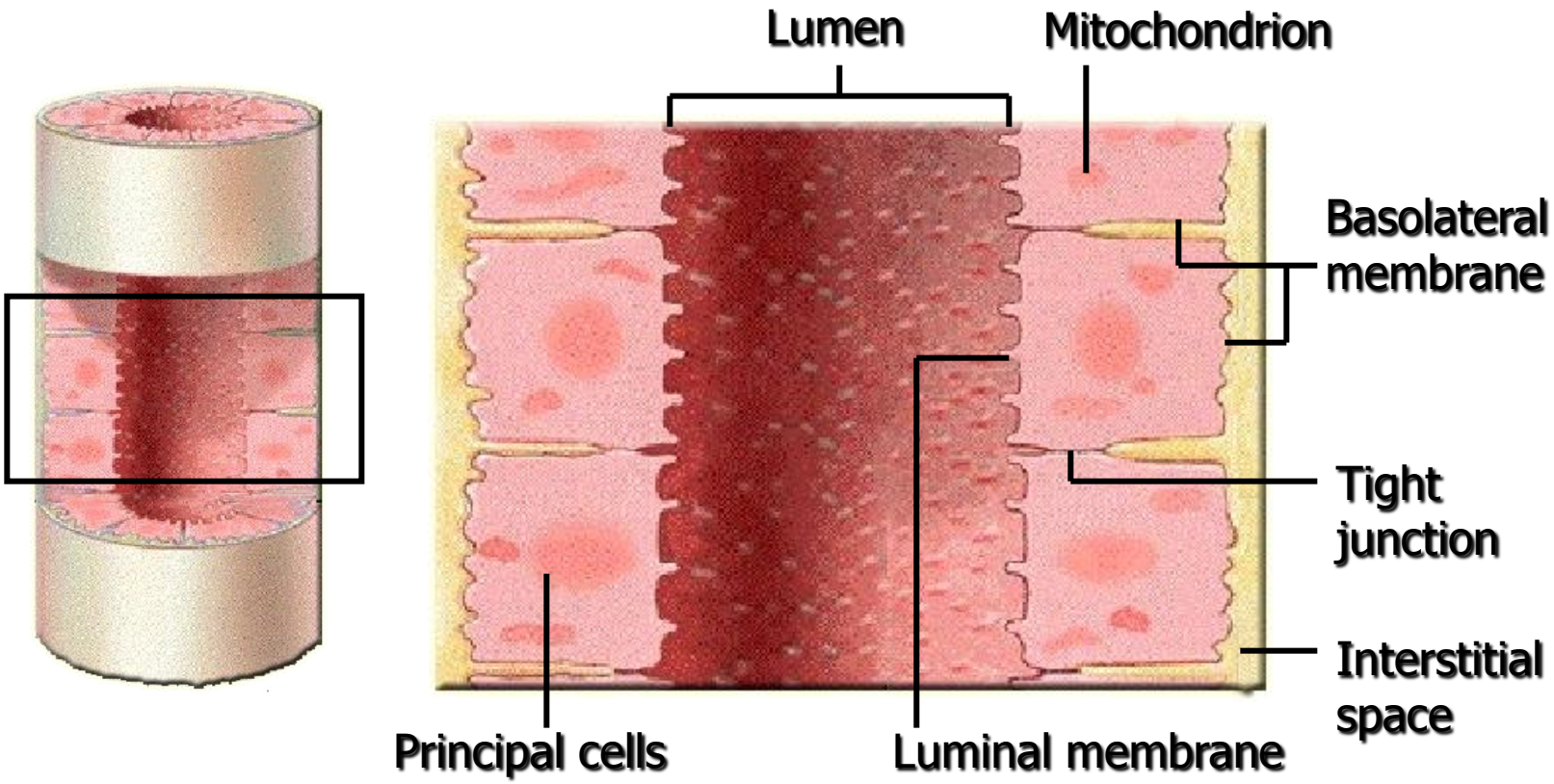
Renal interstitium



Distal Tubule

Cells of the Medullary Collecting Duct

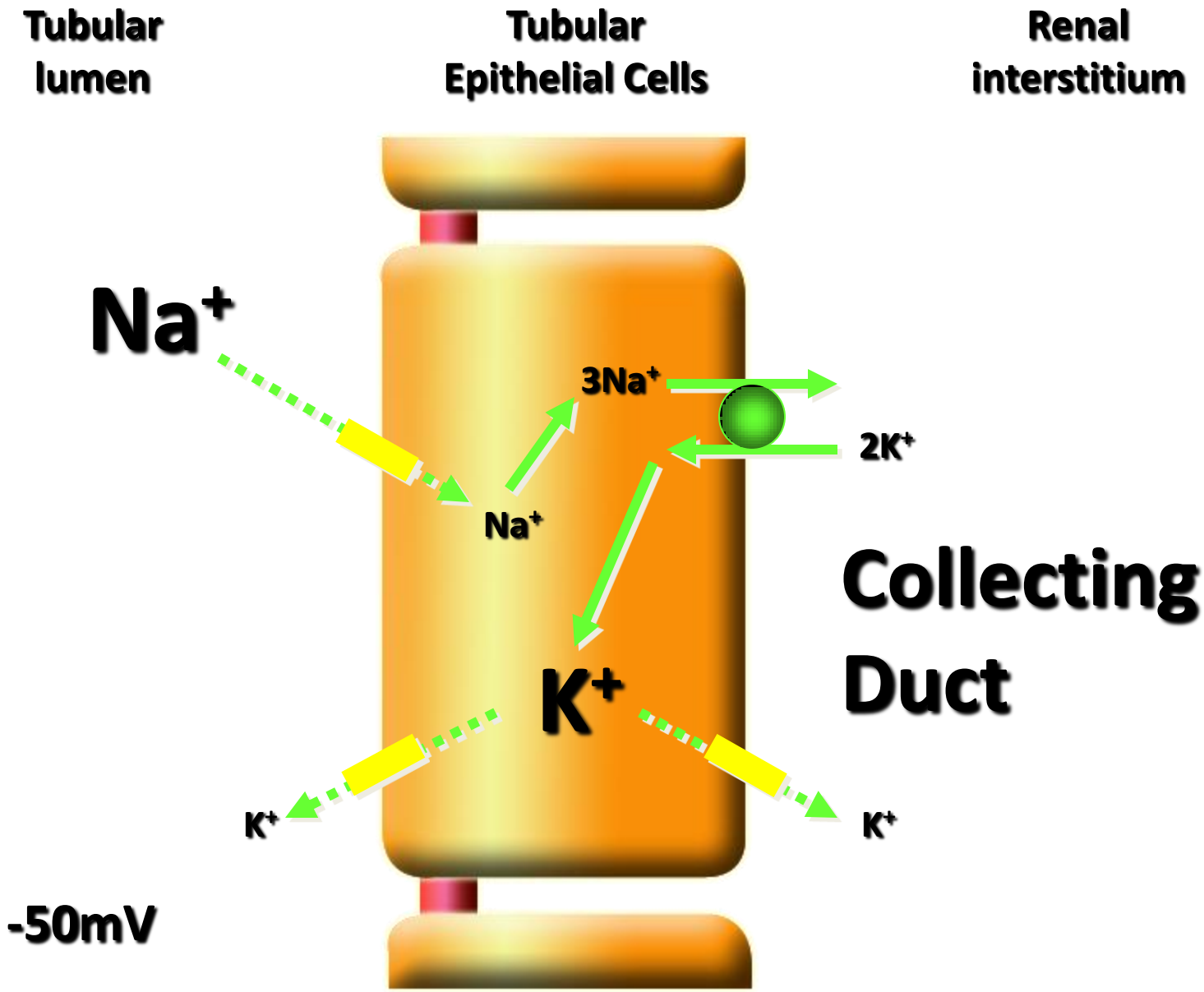
Cells are mainly principal cells.



Hormonally regulated permeability to water and urea.

Collecting duct

- **Water permeable under ADH**
- **Urea is rebsorbed in the presence of ADH**
- **Na reabsorbed in exchange for K under the influence of aldosterone**

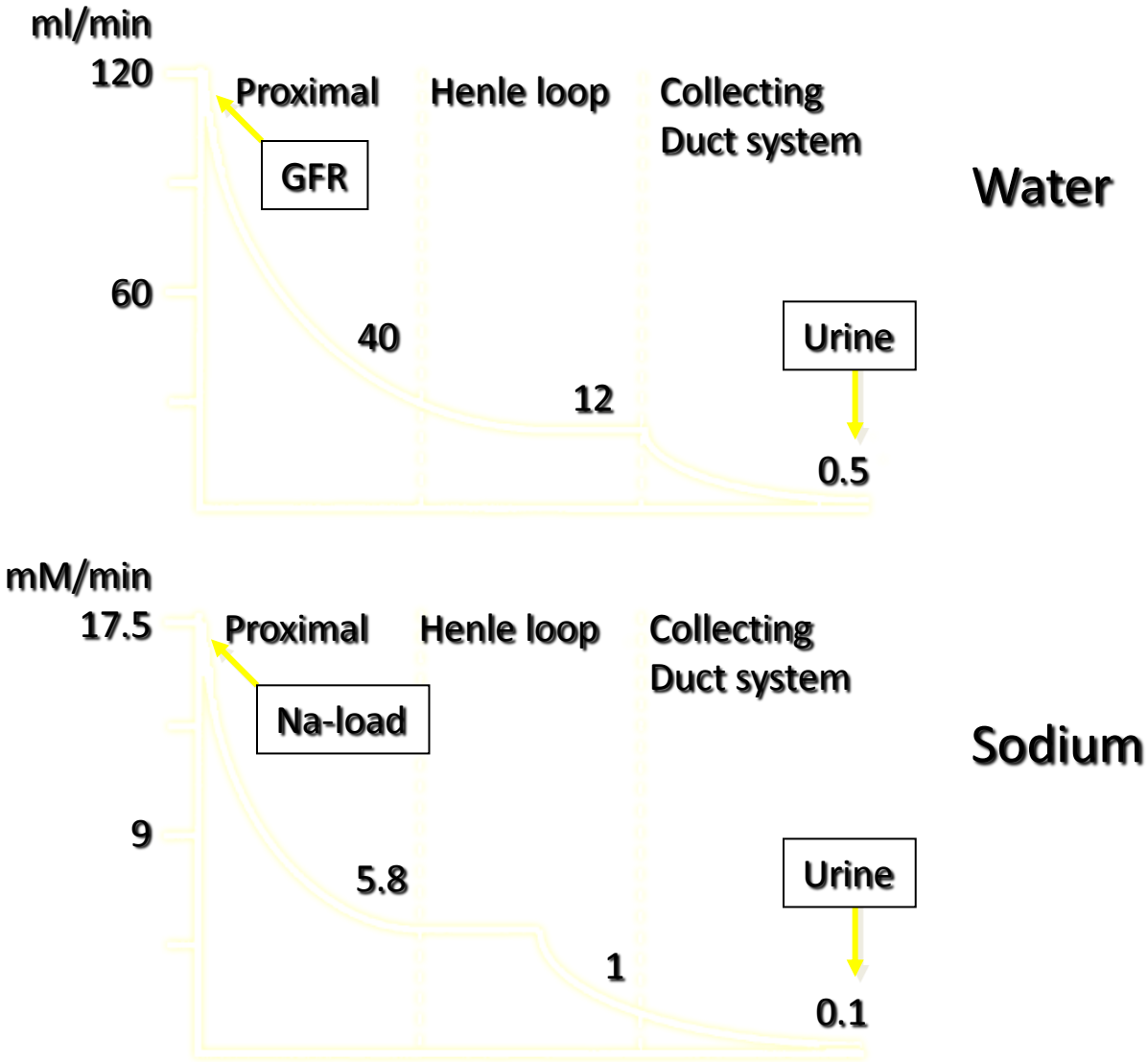

Tubular lumen
Tubular Epithelial Cells
Renal interstitium
Na+
3Na+
2K+
Na+
K+
Collecting Duct
K+
K+
-50mV

Urea Recirculation

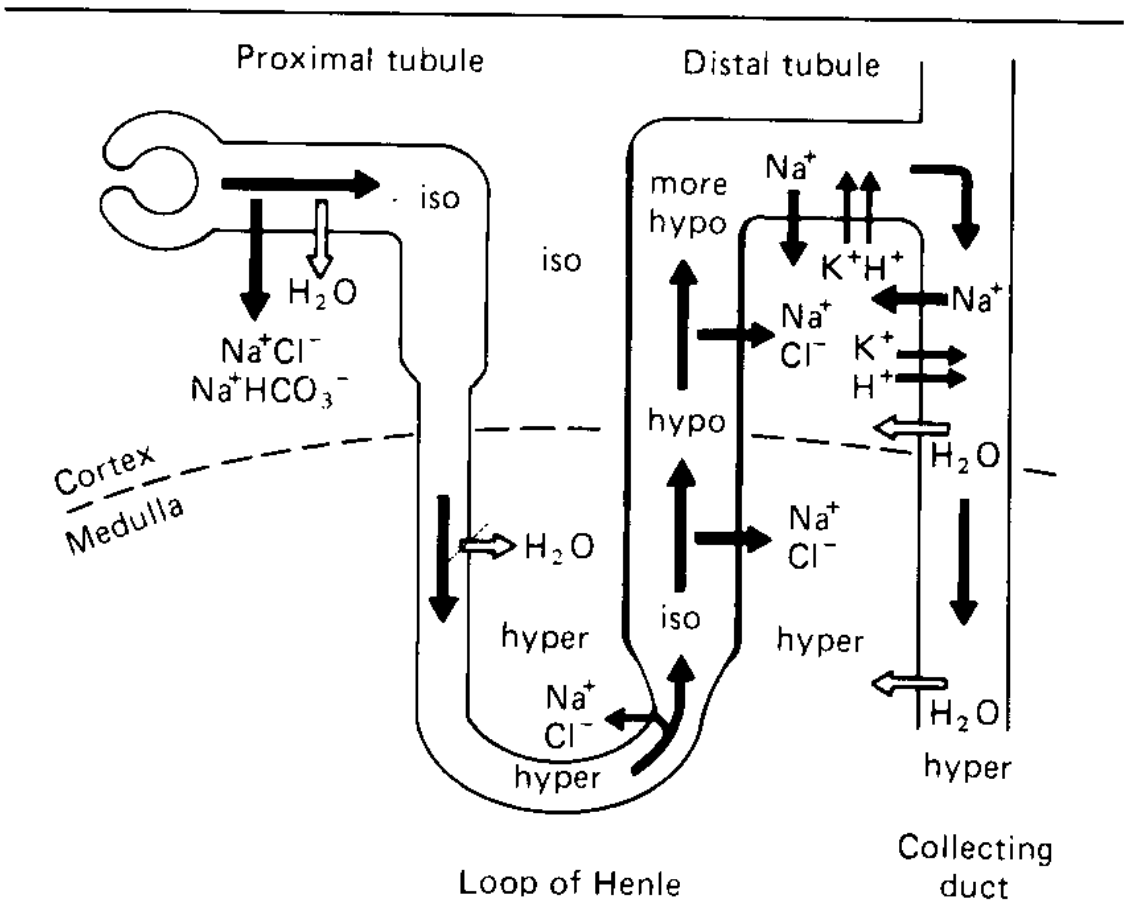
- **Urea is passively reabsorbed in proximal tubule.**
- **In the presence of ADH, water is reabsorbed in distal and collecting tubules, concentrating urea in these parts of the nephron**
- **The inner medullary collecting tubule is highly permeable to urea, which diffuses into the medullary interstitium.**
- **ADH increases urea permeability of medullary collecting tubule.**

Summary of Water transport along the nephron

Segment	% filtered load reabsorbed	Mechanism of H_2O reabsorption	Hormones that regulate H_2O permeability
Proximal tubule	67	Passive	None
Henle's loop	15	DL only; passive	None
Distal tubule	0	No water reabsorption	None
Late distal tubule & collecting duct	~8-17	Passive	ADH


ml/min
120
Proximal
Henle loop
Collecting
Duct system
GFR
Water
60
40
Urine
12
0.5
mM/min
17.5
Proximal
Henle loop
Collecting
Duct system
Na-load
Sodium
9
5.8
Urine
1
0.1
[Na] 145
145
40
200
mEq/l

Osmolality of the filtrate along the nephron



Osmolality of the filtrate along the nephron.

- **Osmolality of filtrate in PCT:**
  - **similar to plasma ~290 mosm**
  - **Due to reabsorption of equal portion of solute & water**
- **Osmolality of filtrate in D loop:**
  - **graded ↑ in osmolality from 300 mosm. To maximum of 1200 mos. at the tip of loop**
  - **Due to only water reabsorption**

Osmolality of the filtrate along the nephron

- **Osmolality of filtrate in A Loop:**
  - **graded ↓ in osmolality 1200-150**
  - **Due to only solute reabsorption**
- **Osmolality of filtrate in Collecting D**
  - **Osmolality depend on ADH**
  - **↑ADH → ↑ water reabsorption → concentrate urine 1200 mosm**
  - **No ADH → no water reabsorption → dilute urine 50mosm**