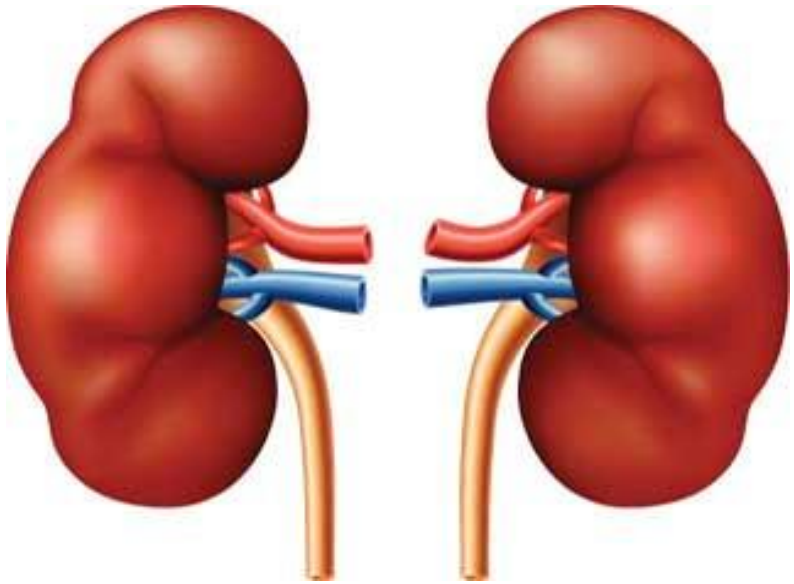
EXCRETORY SYSTEM



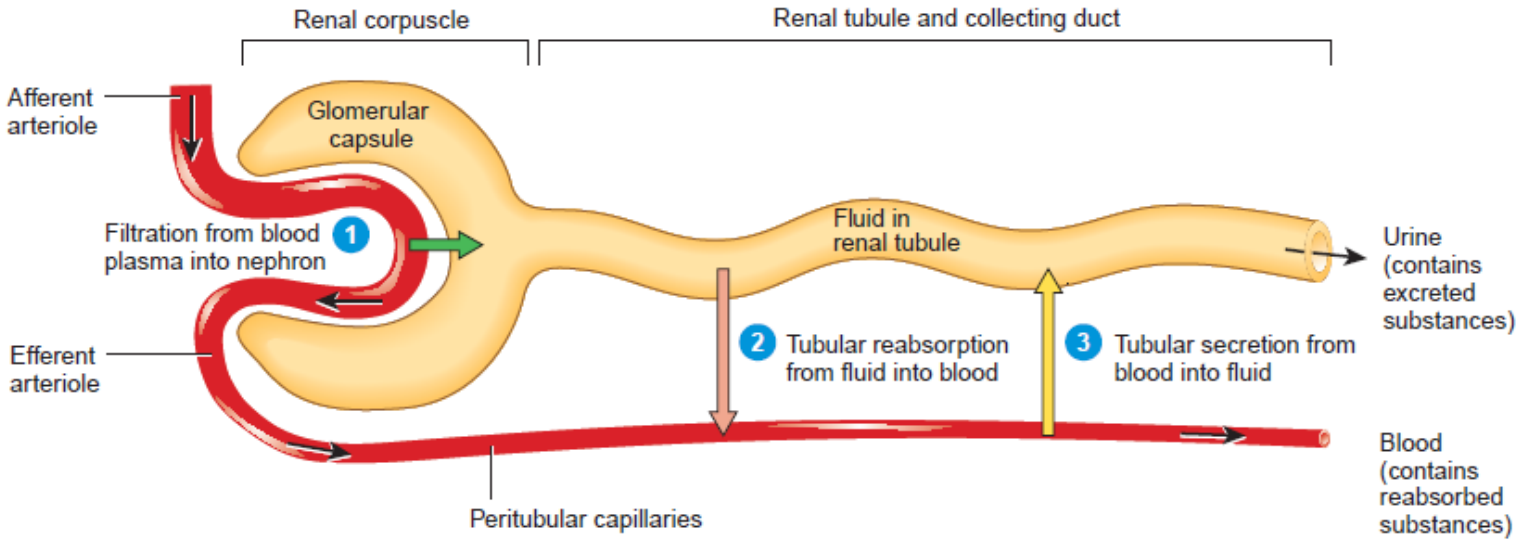
By Dr. Pankaj Panchal
Assistant professor
28/02/2019

FORMATION OF URINE

Formation of urine

3 BASIC PROCESSES:

- Glomerular filtration
- Tubular reabsorption
- Tubular secretion

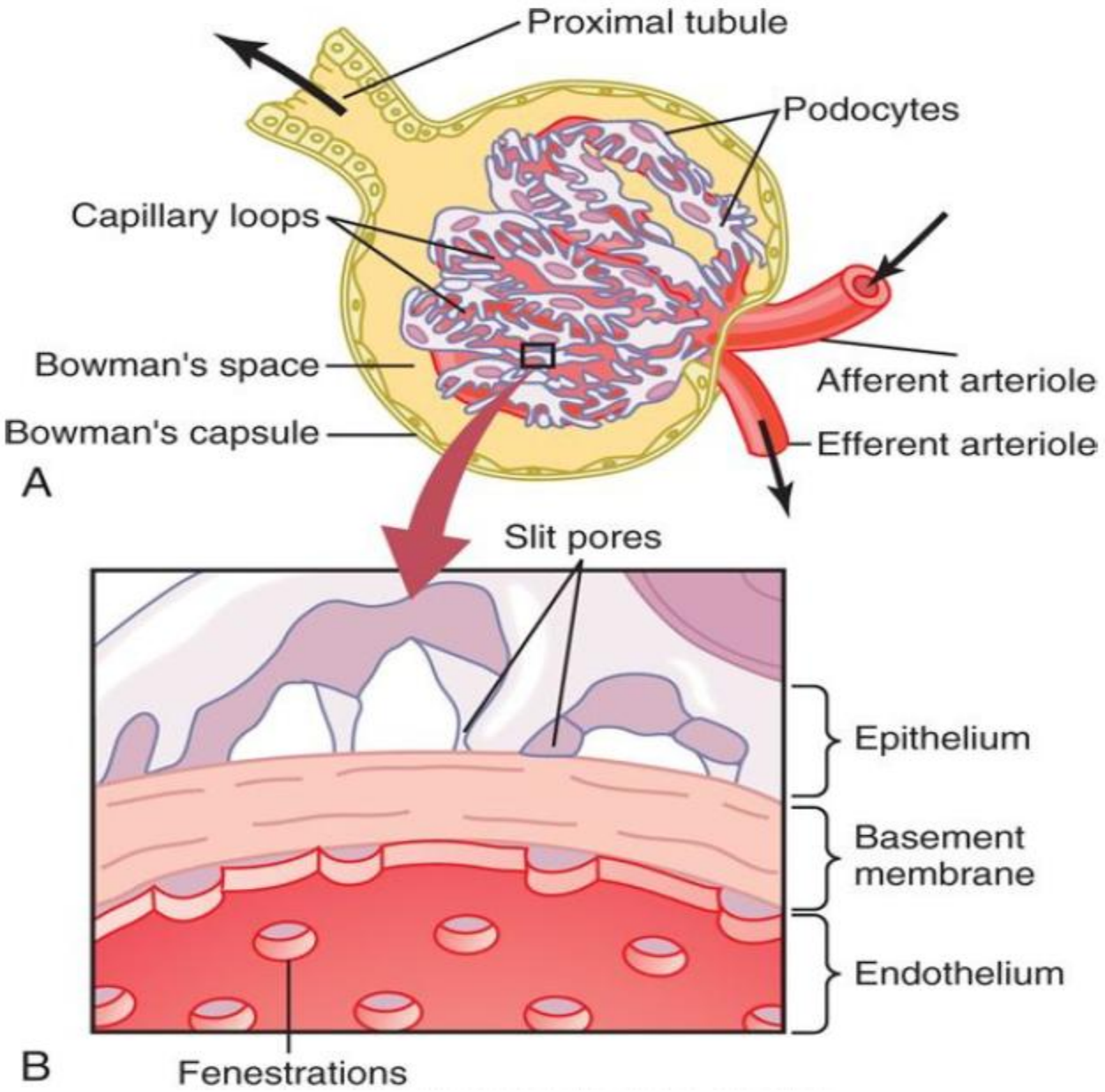


Glomerular filtration

- Renal blood flow -1200ml/min
- **Glomerular filtration rate: 125 ml/min**

  (Amount of filtrate formed by all Nephrons of both kidneys per minute)
- Filtration fraction= GFR/RPF (0.16-0.20)
- Glomerular filtrate

GLOMERULAR MEMBRANE



GFR(glomerular filtration rate)

- **GFR= Kf X Net filtration pressure**

- Net filtration pressure= $(P_G - P_B - \pi_G + \pi_B)$

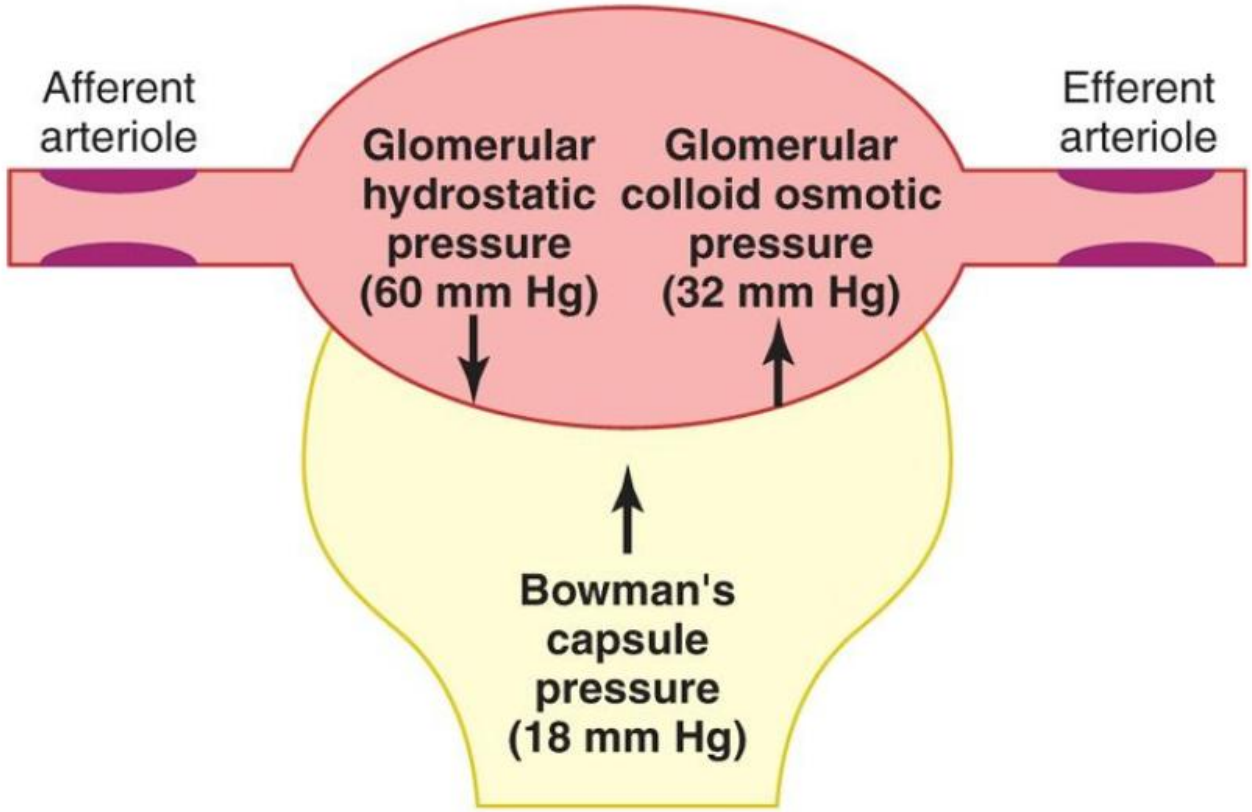
P_G = glomerular hydrostatic pressure

P_B = hydrostatic pressure in bowman's capsule

π_G = colloidal osmotic pressure in glomerular capillary

π_B = colloidal osmotic pressure in bowman's capsule

GFR



Net filtration pressure (10 mm Hg)	=	Glomerular hydrostatic pressure (60 mm Hg)	–	Bowman's capsule pressure (18 mm Hg)	–	Glomerular oncotic pressure (32 mm Hg)

Factors affecting GFR

- Filtration coefficient
- Glomerular hydrostatic pressure (arterial BP, afferent arteriole & efferent arteriole)
- hydrostatic pressure in bowman's capsule
- colloidal osmotic pressure in glomerular capillary
- colloidal osmotic pressure in bowman's capsule

Table 26-2. Factors That Can Decrease the Glomerular Filtration Rate (GFR)

Physical Determinants*	Physiologic/Pathophysiologic Causes
$\downarrow K_f \rightarrow \downarrow$ GFR	Renal disease, diabetes mellitus, hypertension
$\uparrow P_B \rightarrow \downarrow$ GFR	Urinary tract obstruction (e.g., kidney stones)
$\uparrow \pi_G \rightarrow \downarrow$ GFR	$\downarrow$ Renal blood flow, increased plasma proteins
$\downarrow P_G \rightarrow \downarrow$ GFR	
$\downarrow A_P \rightarrow \downarrow P_G$	$\downarrow$ Arterial pressure (has only small effect due to autoregulation)
$\downarrow R_E \rightarrow \downarrow P_G$	$\downarrow$ Angiotensin II (drugs that block angiotensin II formation)
$\uparrow R_A \rightarrow \downarrow P_G$	$\uparrow$ Sympathetic activity, vasoconstrictor hormones (e.g., norepinephrine, endothelin)

Regulation of GFR

Renal autoregulation:

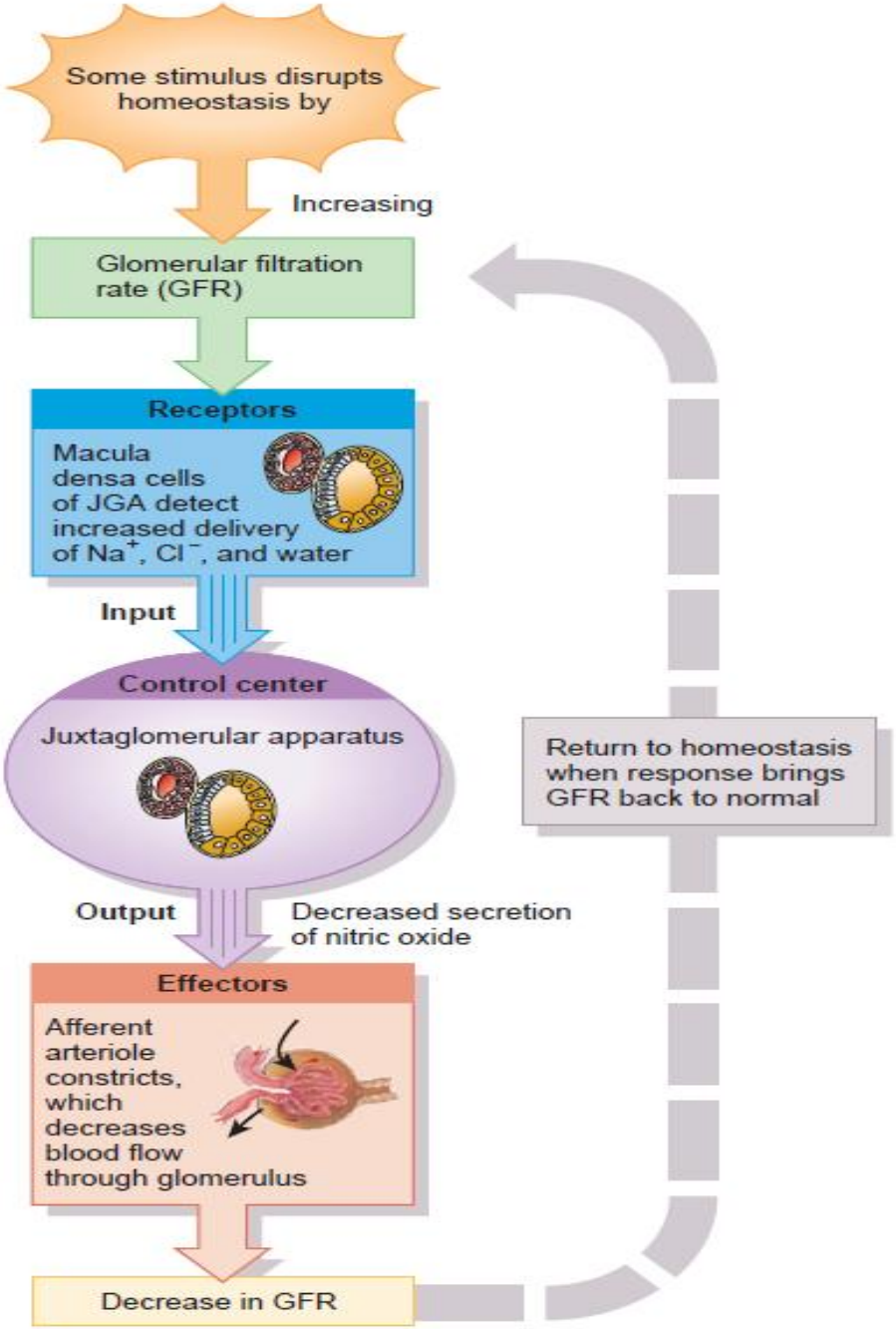
- Myogenic mechanism
- Tubuloglomerular feedback

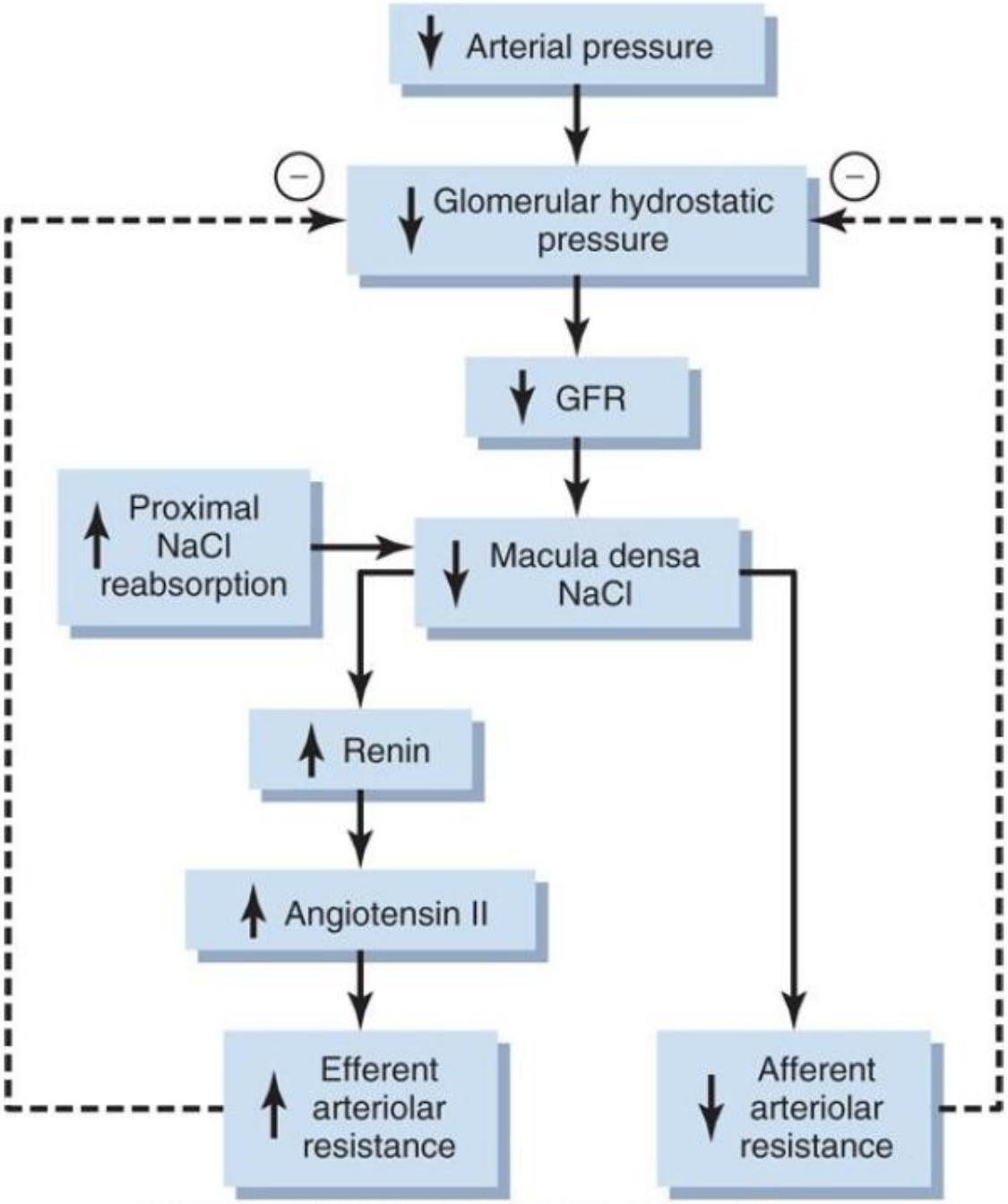
Neural mechanism:

- Sympathetic NS – constricts both afferent & efferent arteriole

Hormonal regulation – angiotensin II & Atrial natriuretic peptide (ANP), nitric oxide, prostaglandins

TUBULOGLOMERULAR FEEDBACK




Arterial pressure
Glomerular hydrostatic pressure
GFR
Proximal NaCl reabsorption
Macula densa NaCl
Renin
Angiotensin II
Efferent arteriolar resistance
Afferent arteriolar resistance

Regulation of Glomerular Filteration Rate (GFR)

TYPE OF REGULATION	MAJOR STIMULUS	MECHANISM AND SITE OF ACTION	EFFECT ON GFR
Renal autoregulation			
Myogenic mechanism	Increased stretching of smooth muscle fibers in afferent arteriole walls due to increased blood pressure.	Stretched smooth muscle fibers contract, thereby narrowing the lumen of the afferent arterioles.	Decrease.
Tubuloglomerular feedback	Rapid delivery of Na^+ and Cl^- to the macula densa due to high systemic blood pressure.	Decreased release of nitric oxide (NO) by the juxtaglomerular apparatus causes constriction of afferent arterioles.	Decrease.
Neural regulation	Increase in level of activity of renal sympathetic nerves releases norepinephrine.	Constriction of afferent arterioles through activation of α_1 receptors and increased release of renin.	Decrease.
Hormone regulation			
Angiotensin II	Decreased blood volume or blood pressure stimulates production of angiotensin II.	Constriction of both afferent and efferent arterioles.	Decrease.
Atrial natriuretic peptide (ANP)	Stretching of the atria of the heart stimulates secretion of ANP.	Relaxation of mesangial cells in glomerulus increases capillary surface area available for filtration.	Increase.

TUBULAR REABSORPTION

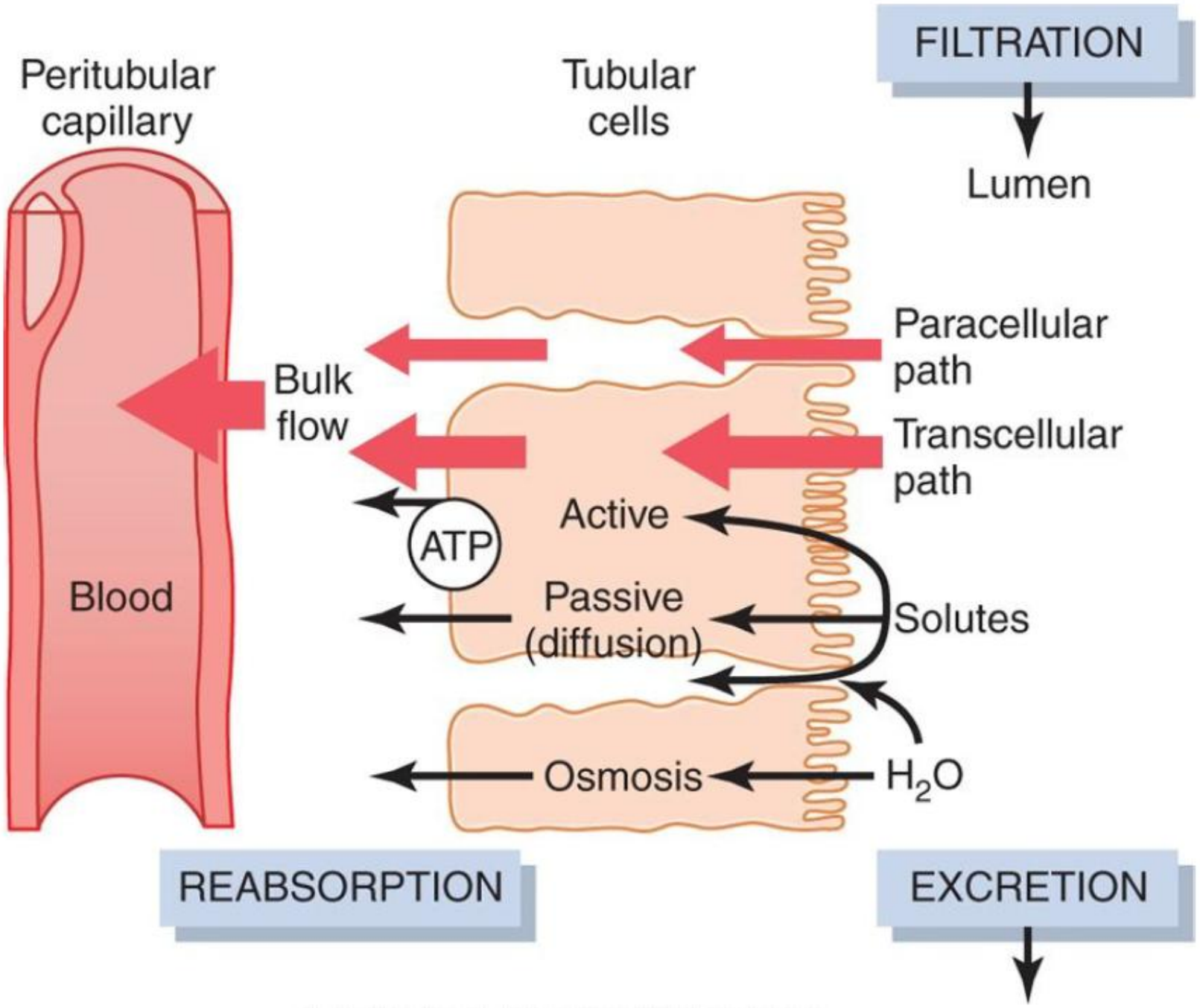
Tubular reabsorption

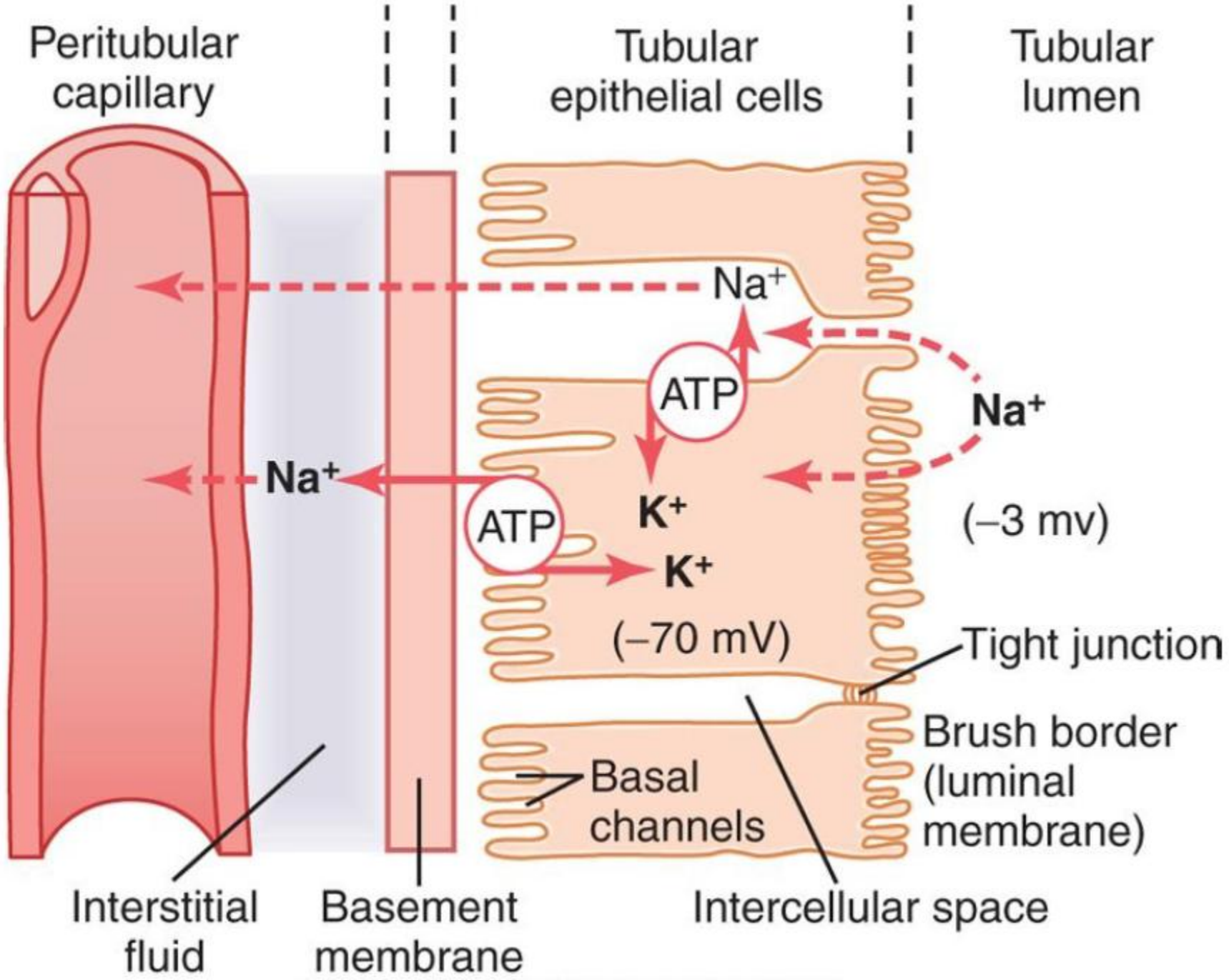
- 99% of filtered water reabsorbed especially through proximal convoluted tubule

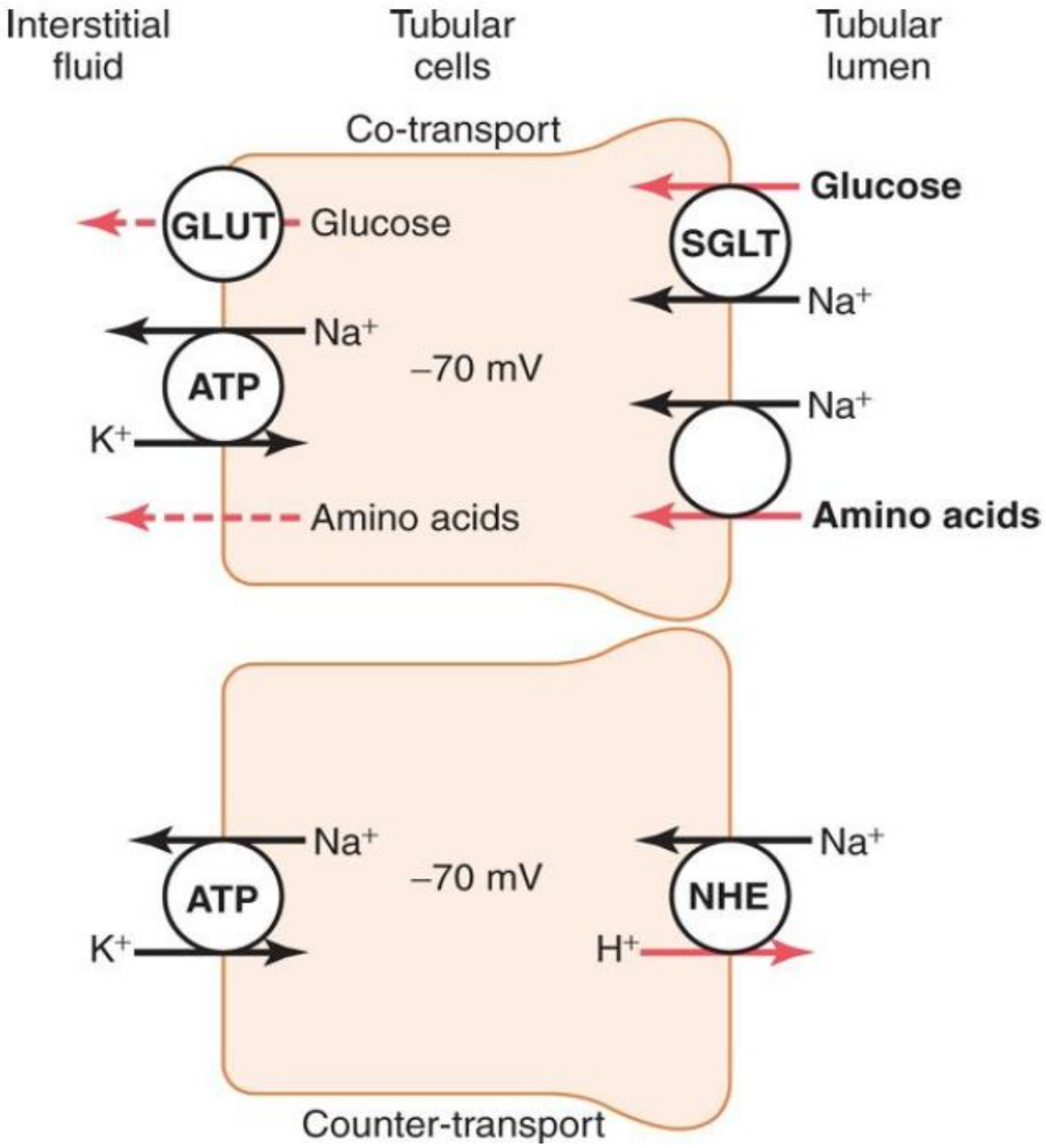
- Solutes reabsorbed by active or passive processes includes glucose, amino acids, urea, ions (Na^+ ,$K,^+$ Ca^{+2}, Cl^- , HCO_3^- , HPO_4^-)

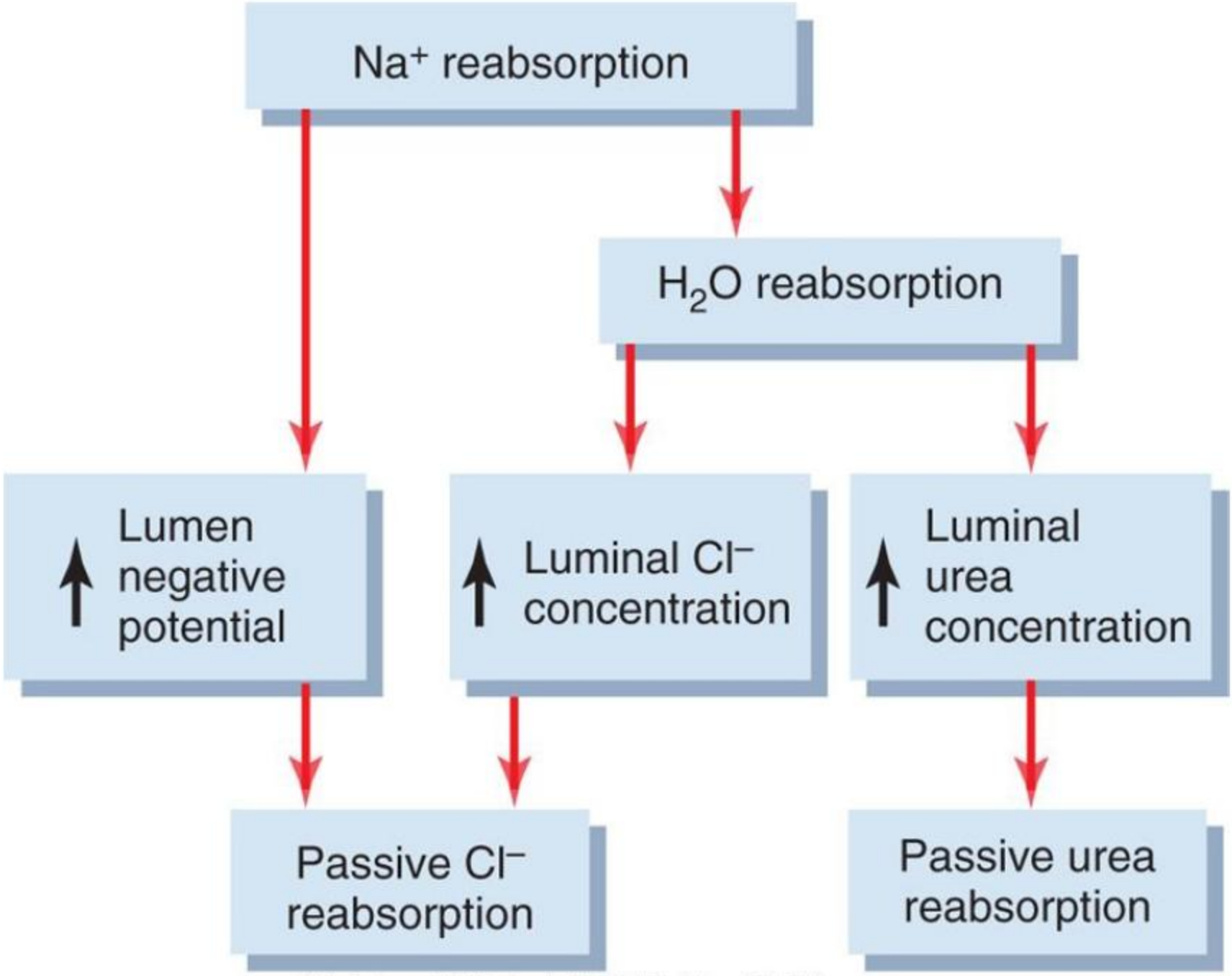
Substances Filtered, Reabsorbed, and Excreted in Urine

SUBSTANCE	FILTERED* (ENTERS GLOMERULAR CAPSULE PER DAY)	REABSORBED (RETURNED TO BLOOD PER DAY)	URINE (EXCRETED PER DAY)
Water	180 liters	178–179 liters	1–2 liters
Proteins	2.0 g	1.9 g	0.1 g
Sodium ions (Na^+)	579 g	575 g	4 g
Chloride ions (Cl^-)	640 g	633.7 g	6.3 g
Bicarbonate ions (HCO_3^-)	275 g	274.97 g	0.03 g
Glucose	162 g	162 g	0 g
Urea	54 g	24 g	30 g†
Potassium ions (K^+)	29.6 g	29.6 g	2.0 g‡
Uric acid	8.5 g	7.7 g	0.8 g
Creatinine	1.6 g	0 g	1.6 g


FILTRATION
Lumen
Peritubular capillary
Tubular cells
Paracellular path
Transcellular path
Bulk flow
Blood
ATP
Active
Passive (diffusion)
Solutes
Osmosis
H_2O
REABSORPTION
EXCRETION


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


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


Na^+ reabsorption
H_2O reabsorption
↑ Lumen negative potential
↑ Luminal Cl^- concentration
↑ Luminal urea concentration
Passive Cl^- reabsorption
Passive urea reabsorption

Transport maximum:-

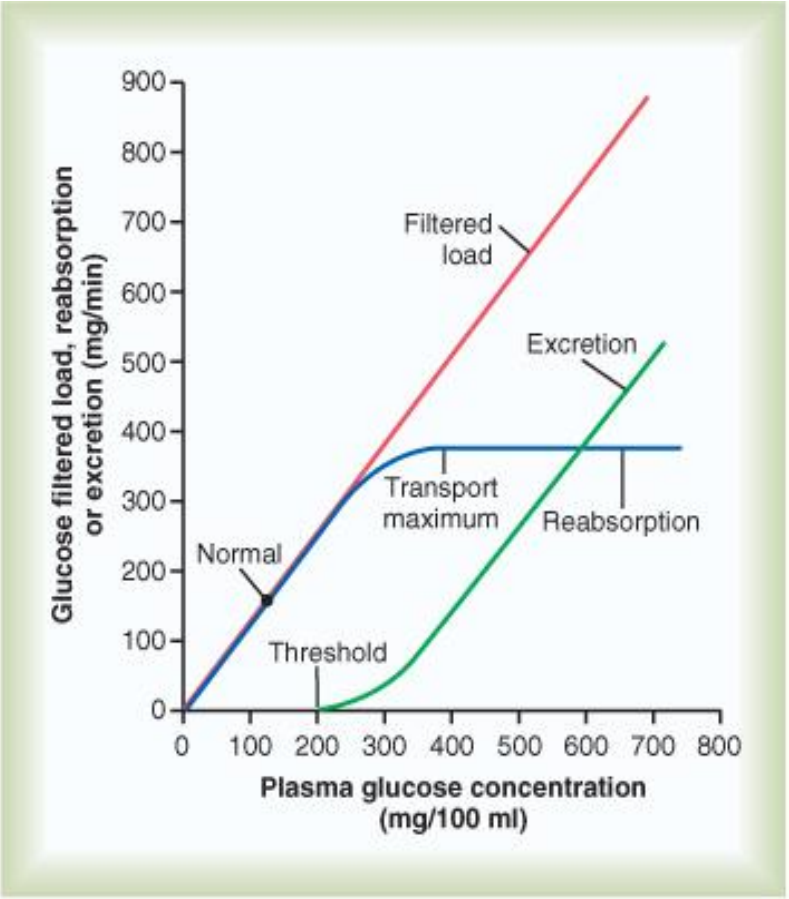
=>it applied to the substances **that actively secreted or reabsorbed.**

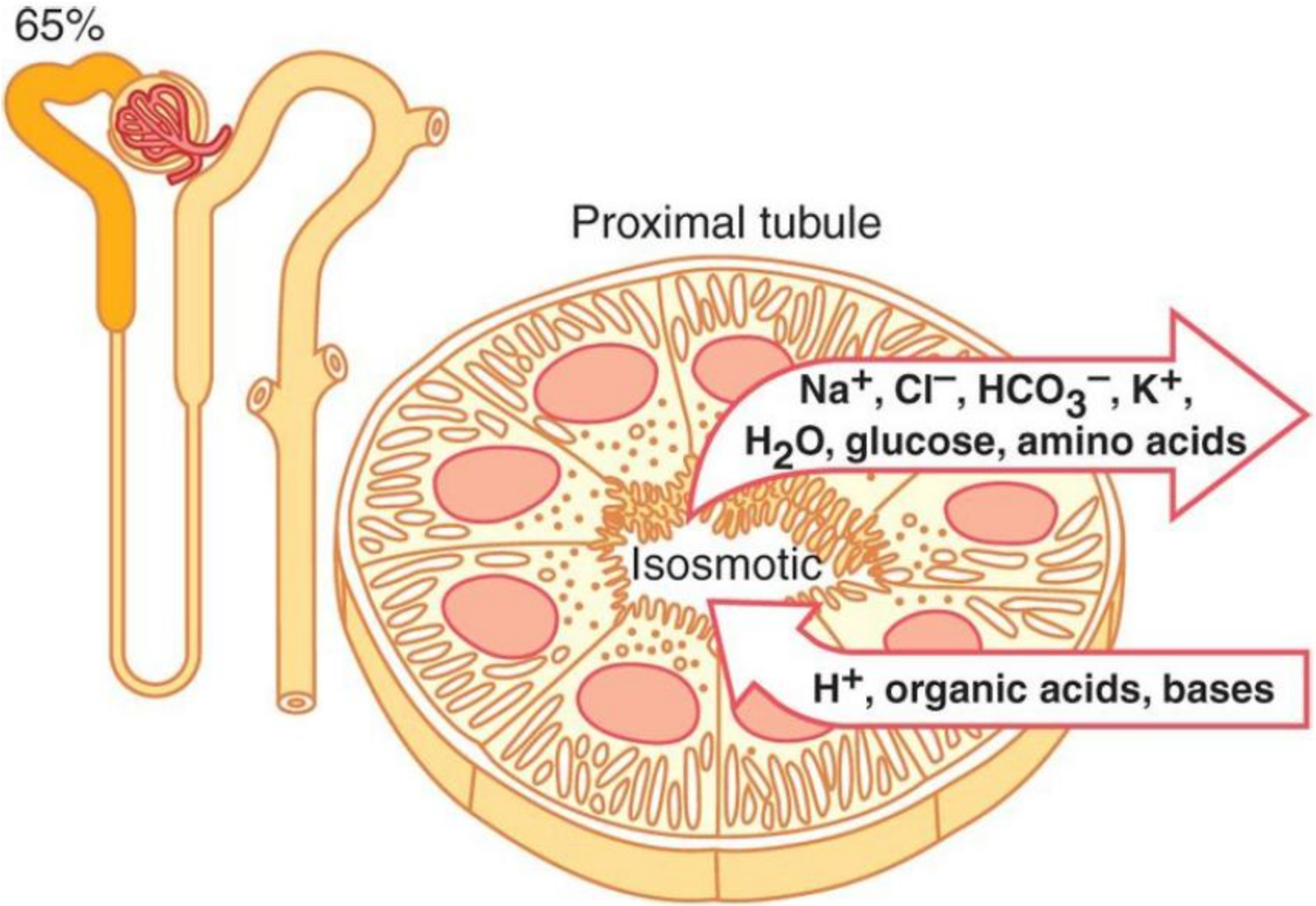
=>It is a rate at which substance is maximally reabsorbed from tubules.

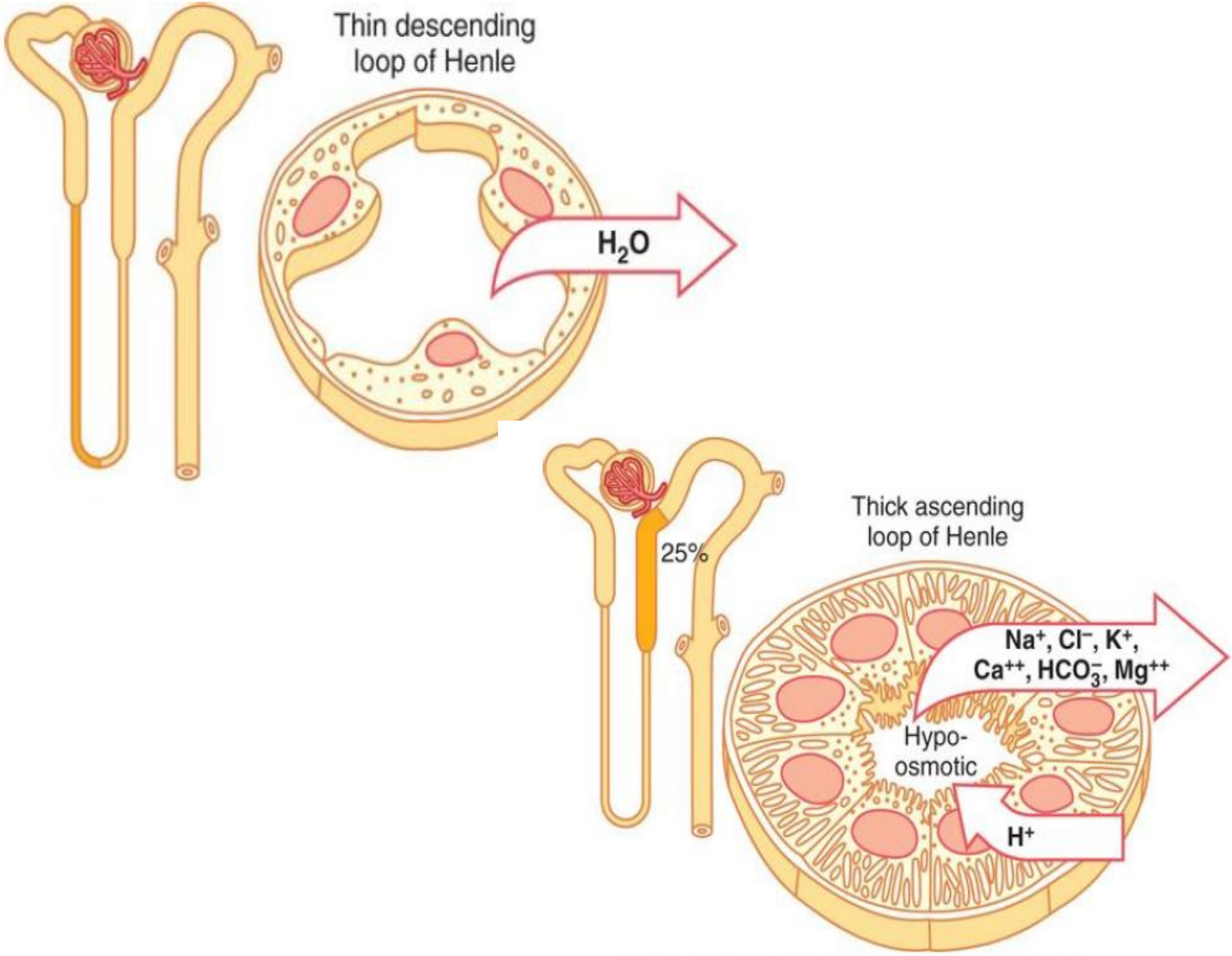
=>**Renal Threshold** is a limit after which substance begin appear in the urine.

=>E.g. transport maximum for glucose is 375mg/min

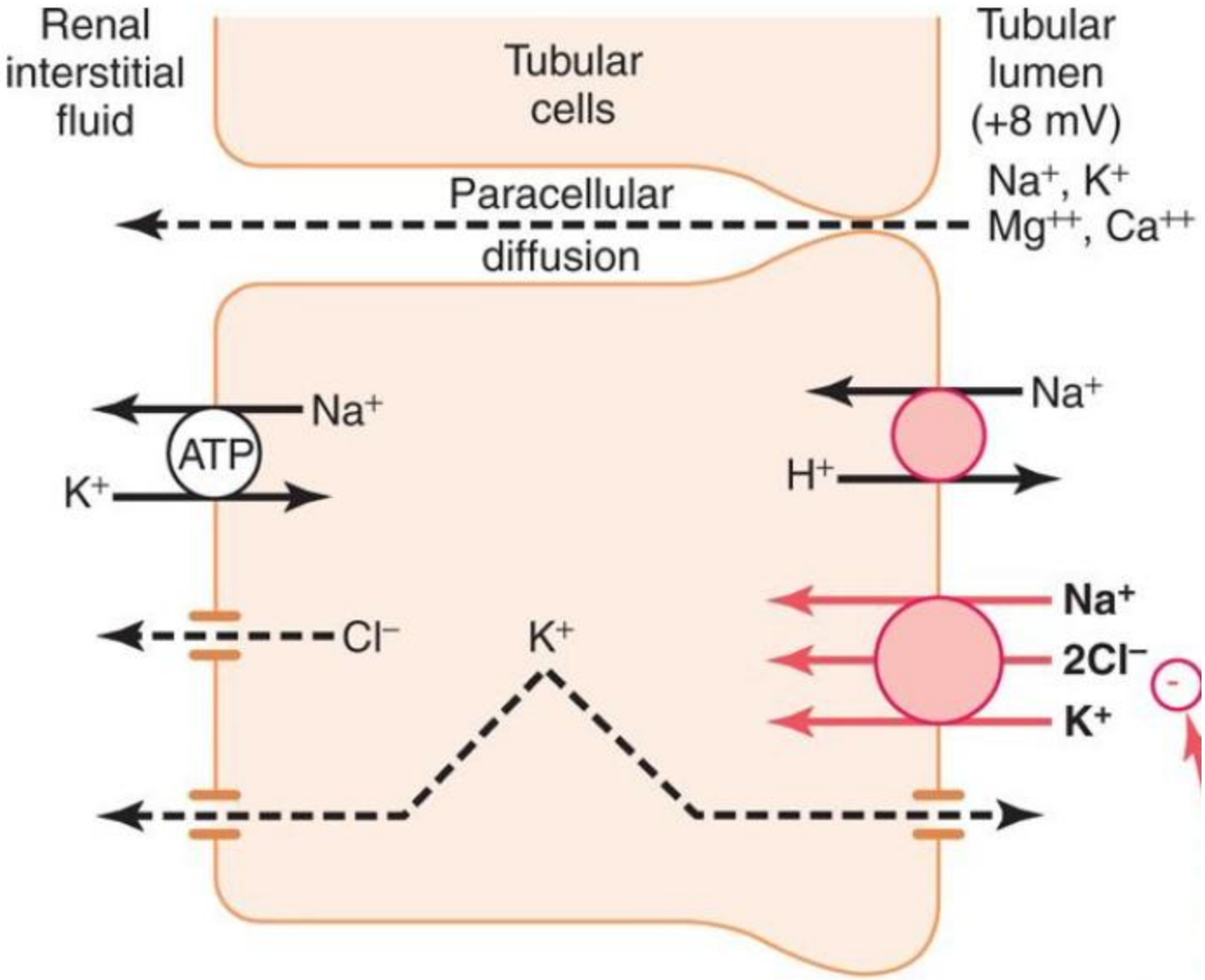
=>Some substances like creatinine and PAH that is actively secreted also exhibit transport maximum..



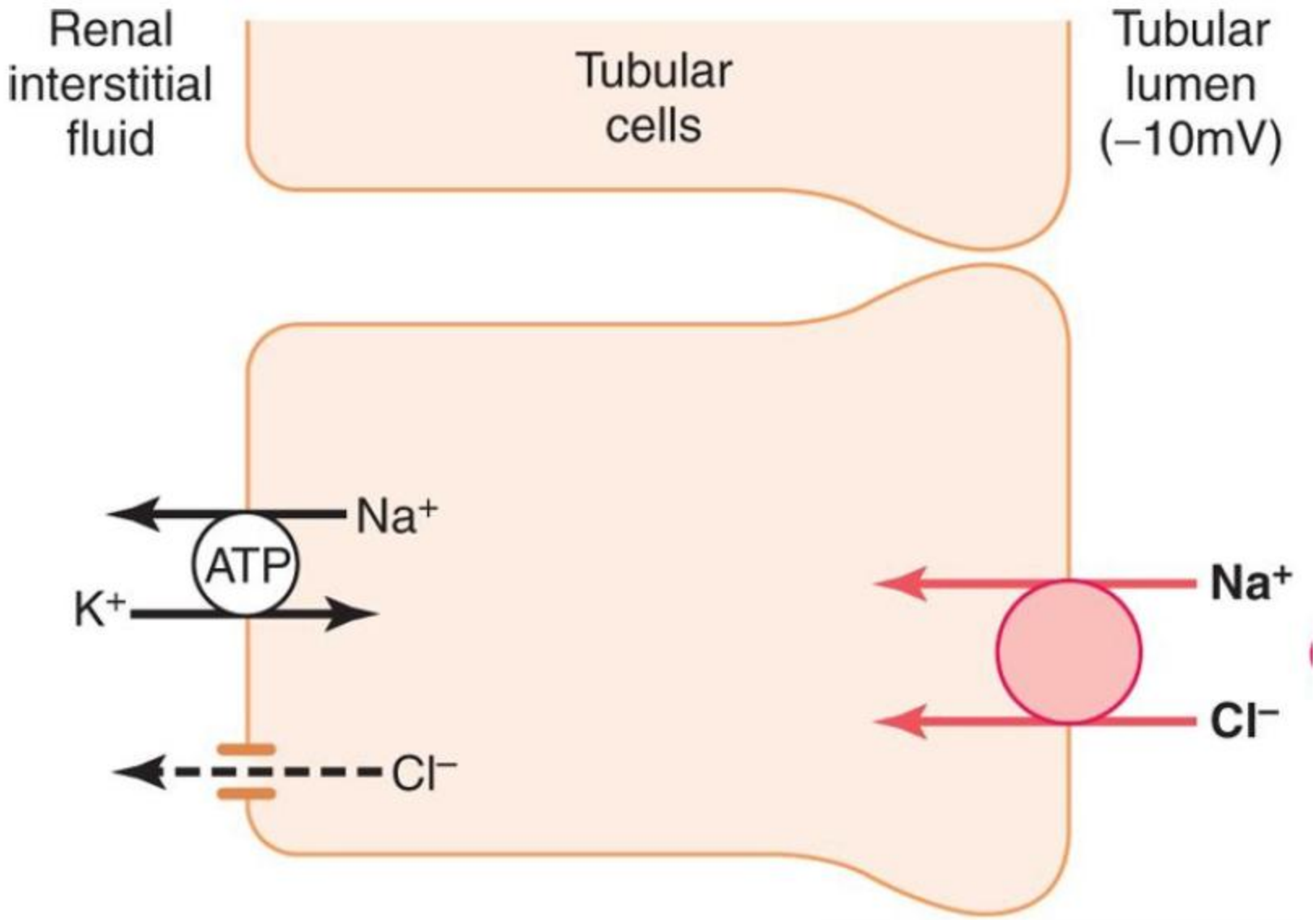

65%
Proximal tubule
Na^+, Cl^-, HCO_3^-, K^+,
H_2O, glucose, amino acids
Isosmotic
H^+, organic acids, bases

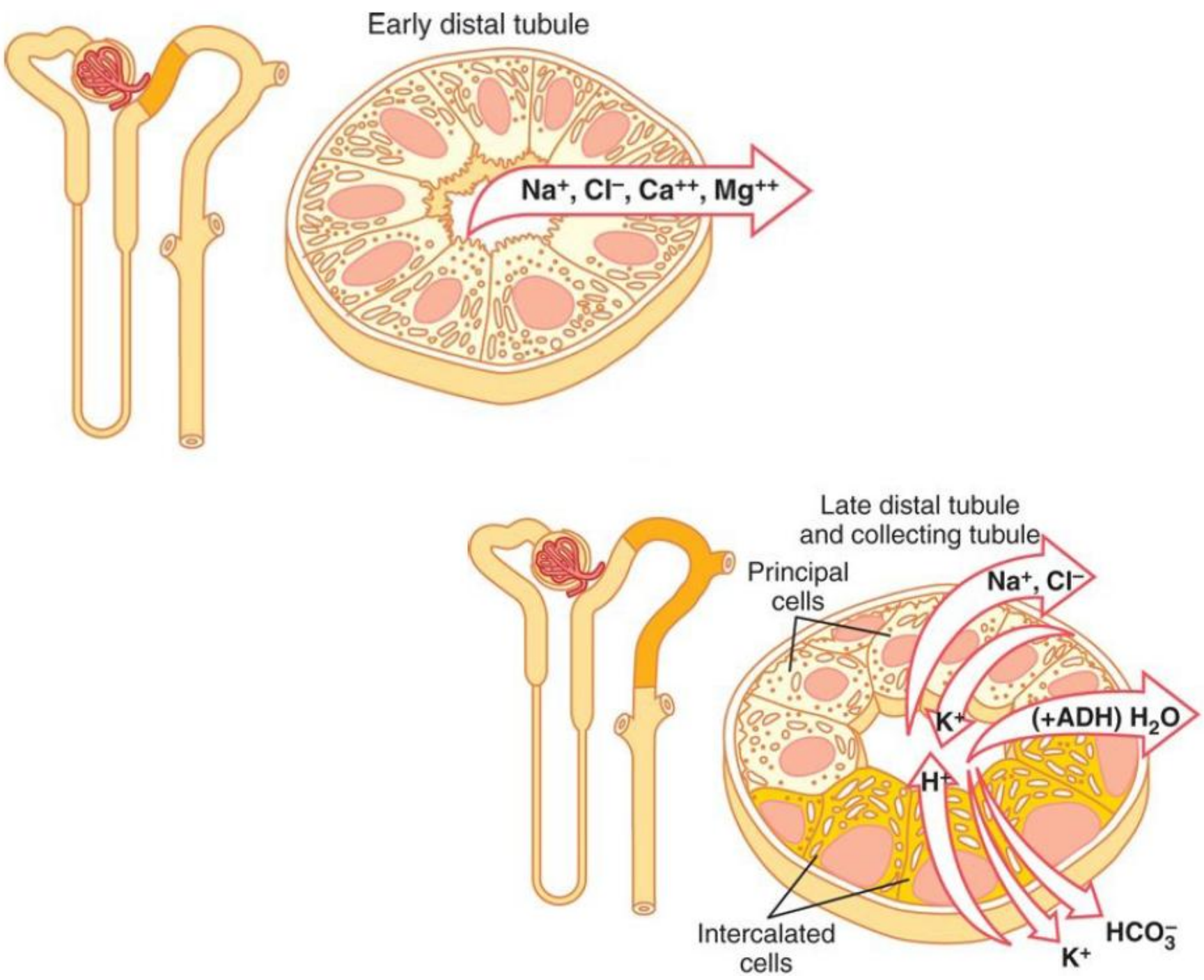

Thin descending
loop of Henle
H_2O
25%
Thick ascending
loop of Henle
Na^+, Cl^-, K^+,
Ca^{++}, HCO_3^-, Mg^{++}
Hypo-
osmotic
H^+

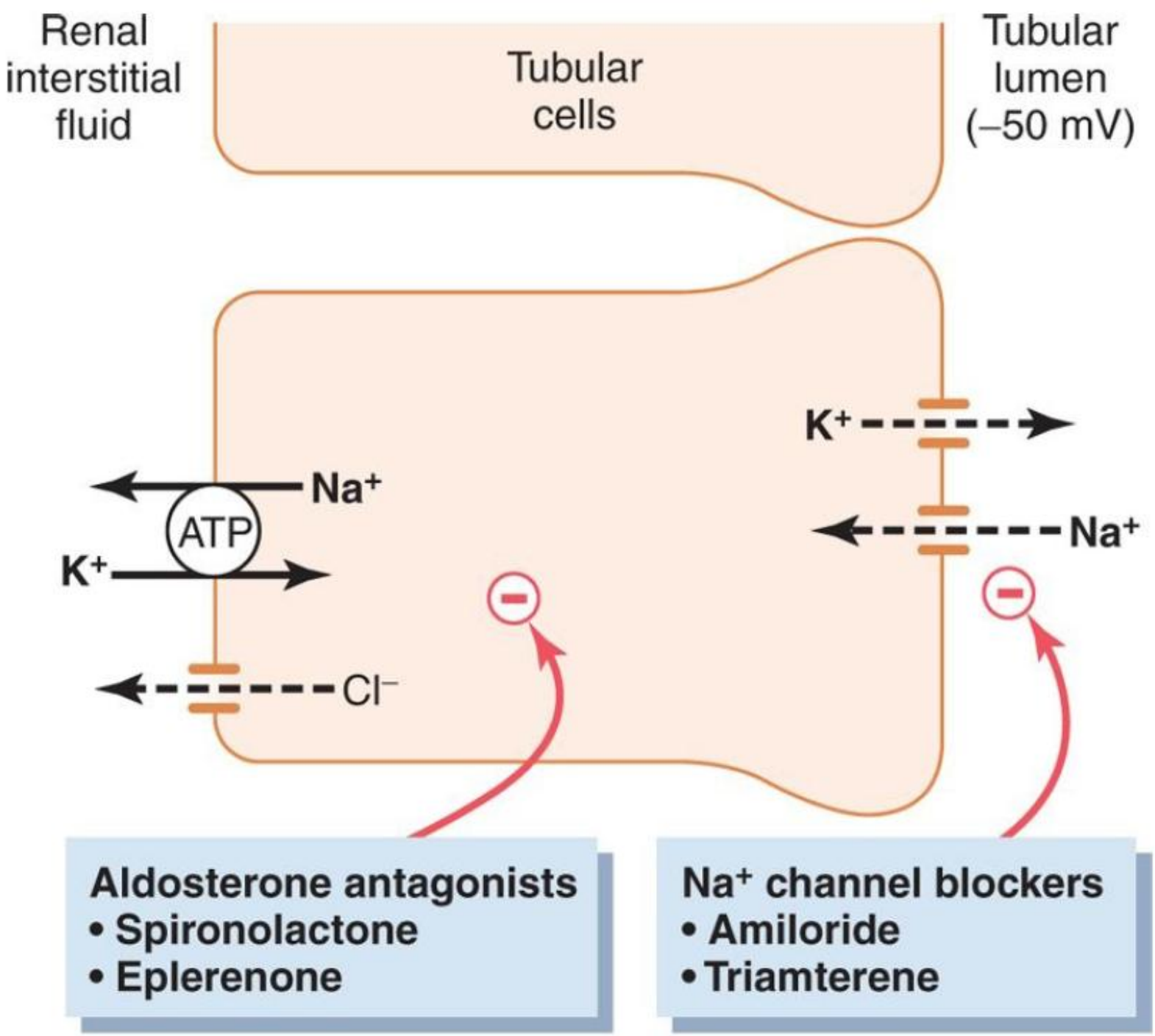
THICK ASCENDING LIMB OF LOOP OF HENLE



Early distal tubule NaCl transport

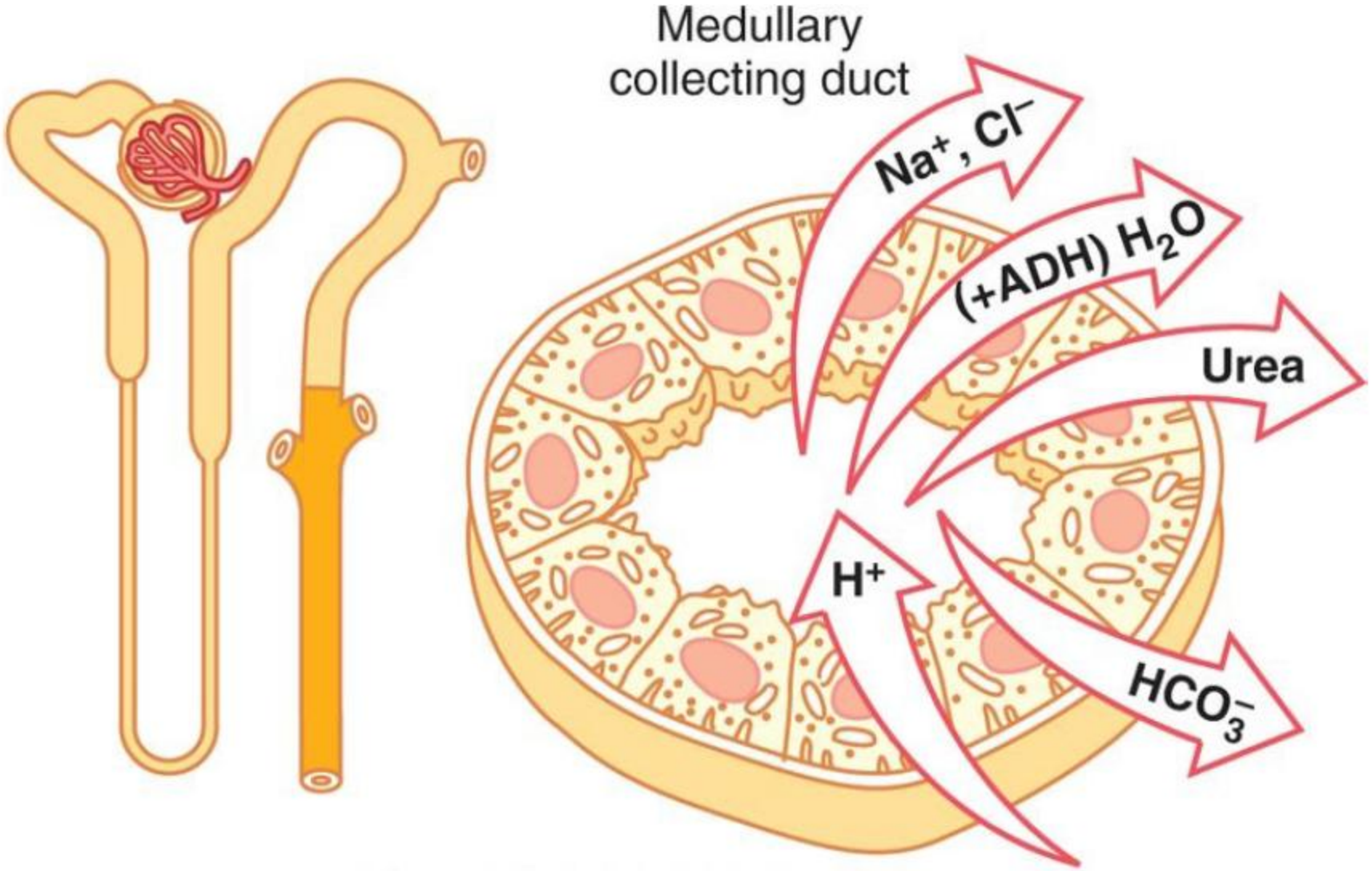



Early distal tubule
Na+, Cl–, Ca++, Mg++
Late distal tubule
and collecting tubule
Principal
cells
Na+, Cl–
K+
(+ADH) H2O
H+
Intercalated
cells
HCO3–
K+


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

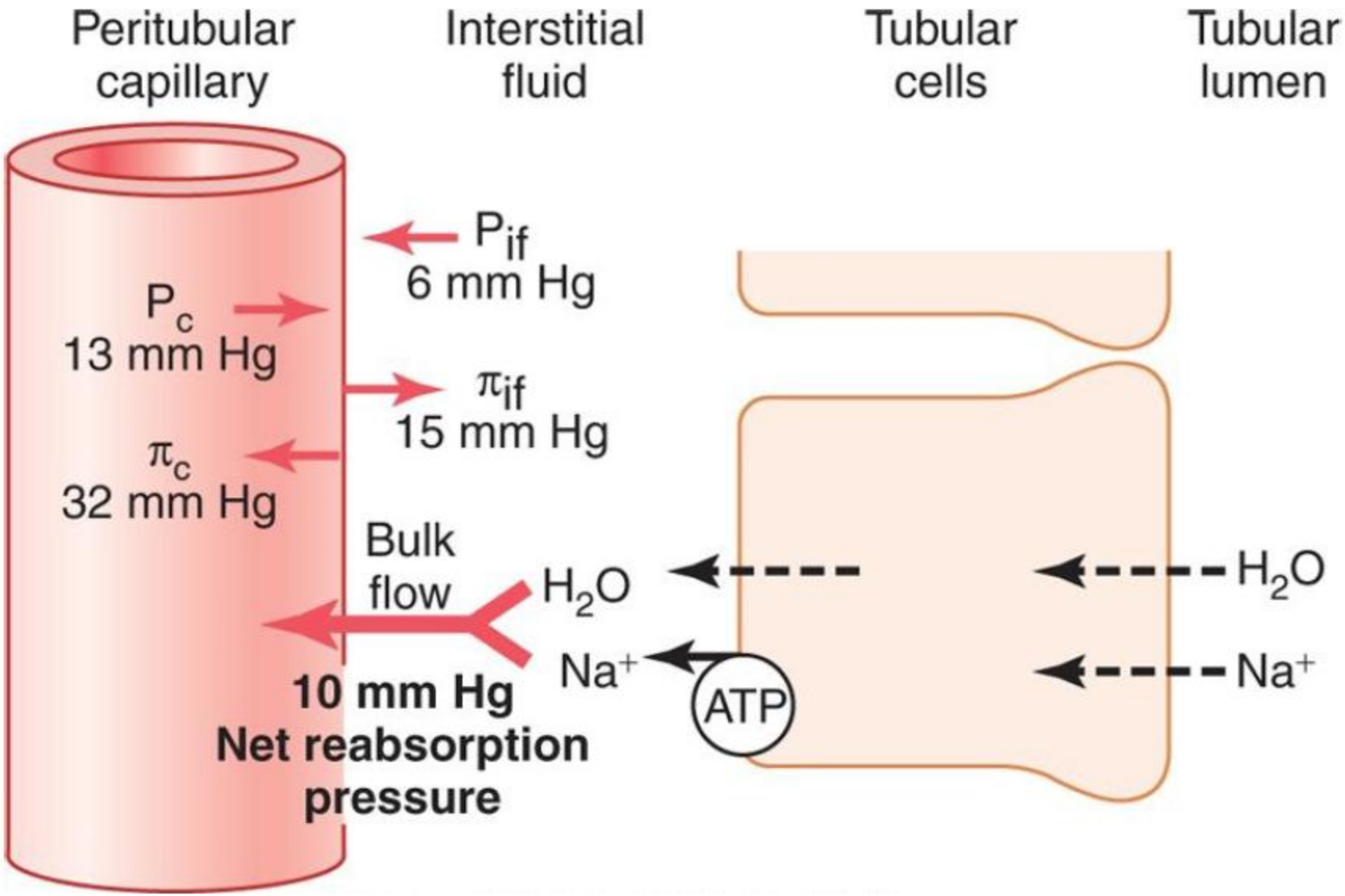
Functional characteristics of late distal tubule & cortical collecting ducts

- Impermeable to urea
- Sodium reabsorption controlled by **aldosterone**
- Active secretion of H+ (1000:1) by H+ ATPase pump
- Water reabsorption regulated by **ADH**


Medullary
collecting duct
Na^+, Cl^-
(+ADH) H_2O
Urea
H^+
HCO_3^-

Functional characteristics of Medullary collecting ducts

- Permeable to urea (special urea transporters)
- Water permeability regulated by ADH
- Active H+ secretion (so, Helps in acid base balance)


Peritubular capillary
Interstitial fluid
Tubular cells
Tubular lumen
P_{if}
6 mm Hg
P_c
13 mm Hg
π_{if}
15 mm Hg
π_c
32 mm Hg
Bulk flow
H_2O
Na^+
ATP
H_2O
Na^+
10 mm Hg
Net reabsorption pressure

Regulation of tubular reabsorption

- **Glomerulotubular balance:**

  Ability of tubules to increase reabsorption rate in response to increased tubular load
- **Peritubular capillary & renal interstitial fluid forces**
- **Effects of arterial BP** –pressure diuresis & pressure natriuresis
- **Hormones** – ADH, Aldosterone,

  AT-II, ANP, PTH