In The Name Of God

C H A P T E R 2 8

Renal Tubular reabsorption and secretion

هدف کلی جلسه: شناخت مکانیسم بازجذب و ترشح توبولی

اهداف ویژه جلسه

در پایان دانشجو قادر باشد:

- مبانی کلی بازجذب و ترشح را شرح دهد
- مکانیسم بازجذب و ترشح را در توبولها توضیح دهد
- روش بازجذب آب و نحوه جفت شدن بازجذب مواد مختلف با بازجذب سدیم را شرح دهد
- نقش بخش های مختلف توبولی در پردازش فیلترای گلومرولی را توضیح دهد
- نقش سلولهای اینترکاله را در تنظیم دفع پتاسیم و بیکربنات شرح دهد
- نقش تعادل گلومرولی-توبولی را در تنظیم میزان بازجذب توبولی توضیح دهد
- عوامل مختلف تنظیم کننده میزان دفع سدیم و نحوه اثر هرکدام را نام ببرد
- نیروهای موثر در بازجذب مواد را شرح دهد

Reabsorption and Secretion by the Renal Tubules

Urinary excretion rate = Filtration rate
– Reabsorption rate + Secretion rate

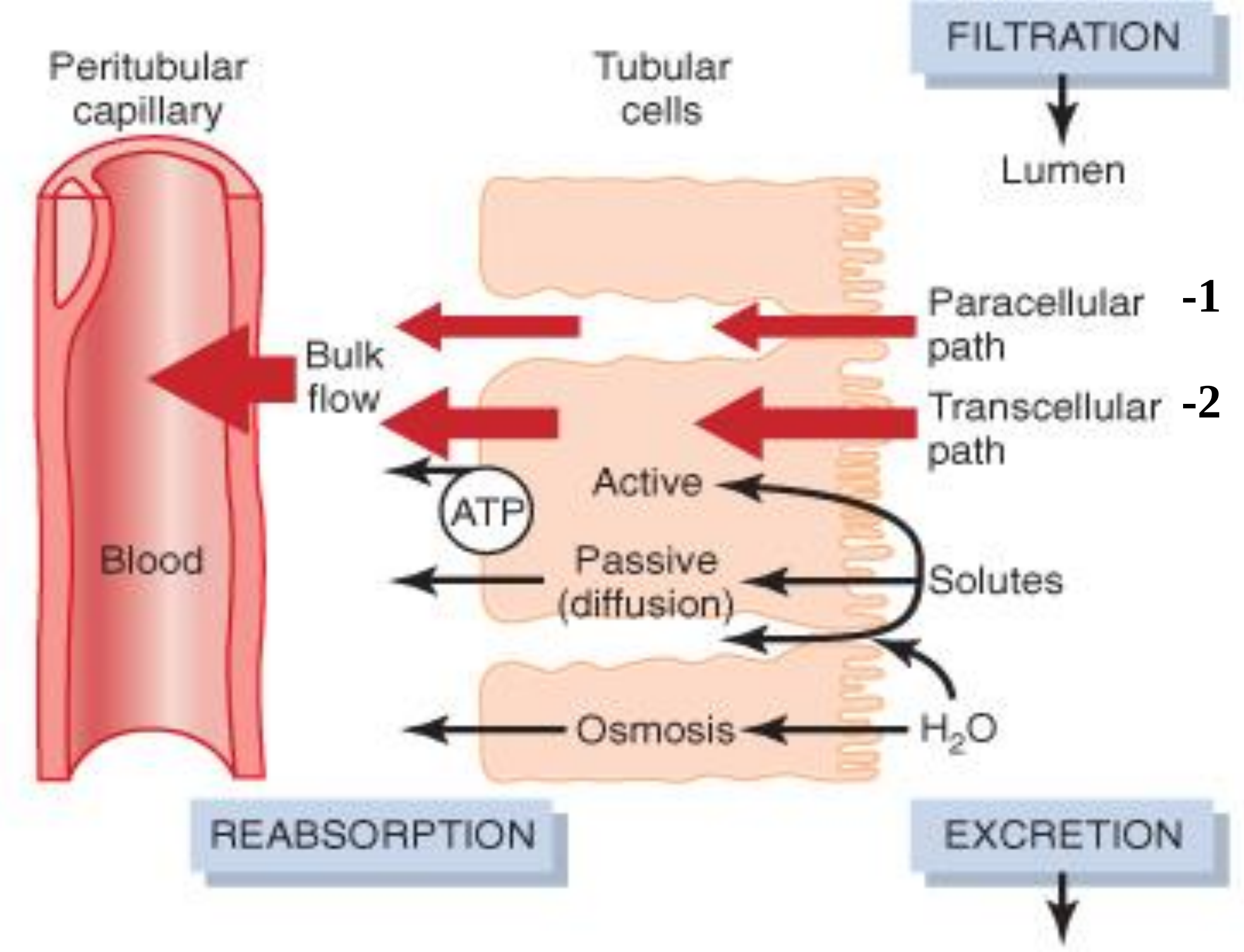
Tubular Reabsorption Is Selective and Quantitatively Large

	Amount Filtered	Amount Reabsorbed	Amount Excreted	% of Filtered Load Reabsorbed
Glucose (g/day)	180	180	0	100
Bicarbonate (mEq/day)	4,320	4,318	2	>99.9
Sodium (mEq/day)	25,560	25,410	150	99.4
Chloride (mEq/day)	19,440	19,260	180	99.1
Potassium (mEq/day)	756	664	92	87.8
Urea (g/day)	46.8	23.4	23.4	50
Creatinine (g/day)	1.8	0	1.8	0

Filtration load = GFR × Plasma concentration

- **Tubular Reabsorption Includes Passive and Active Mechanisms**

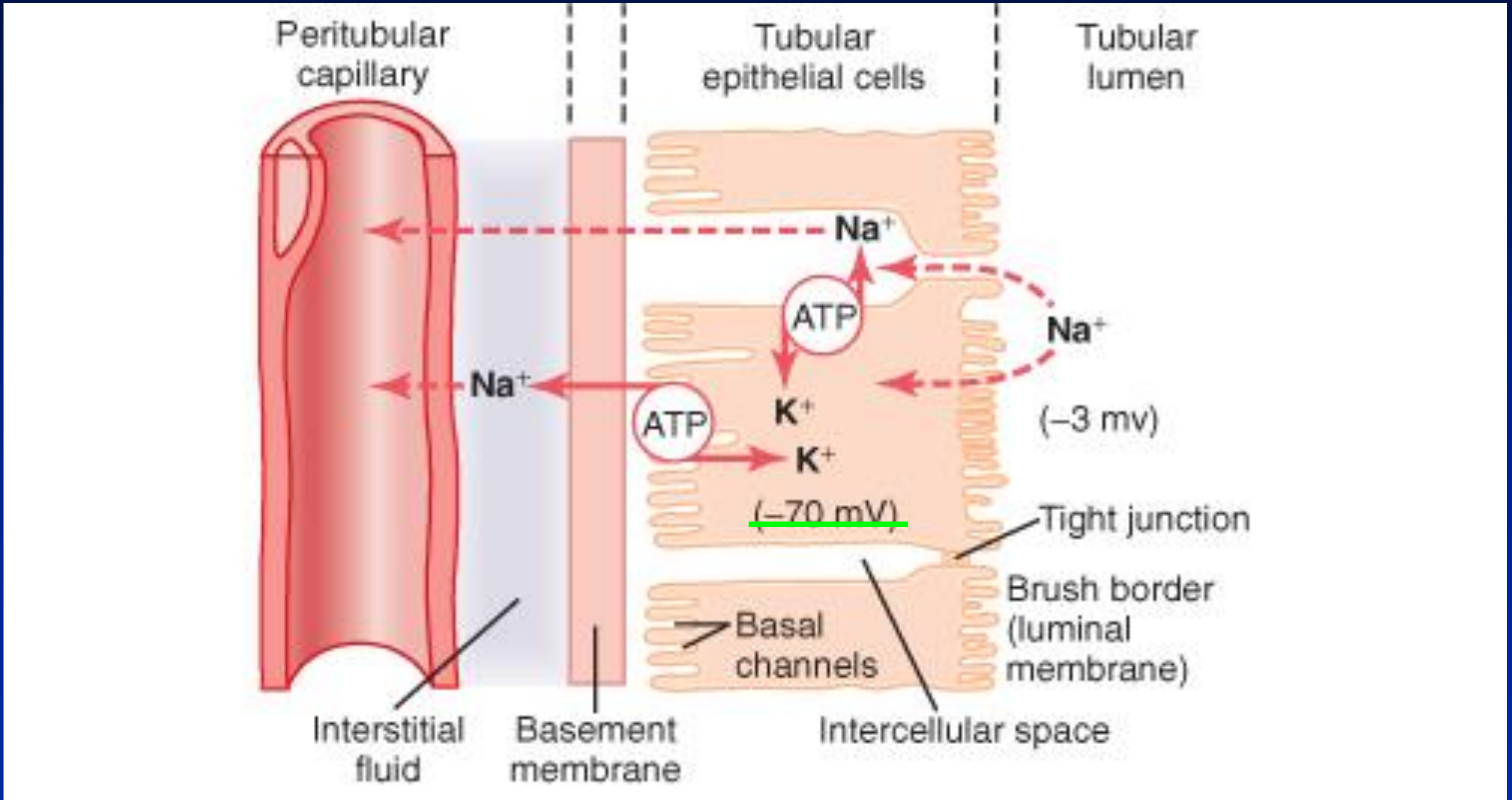
Two routes for reabsorption of filtered water and solutes



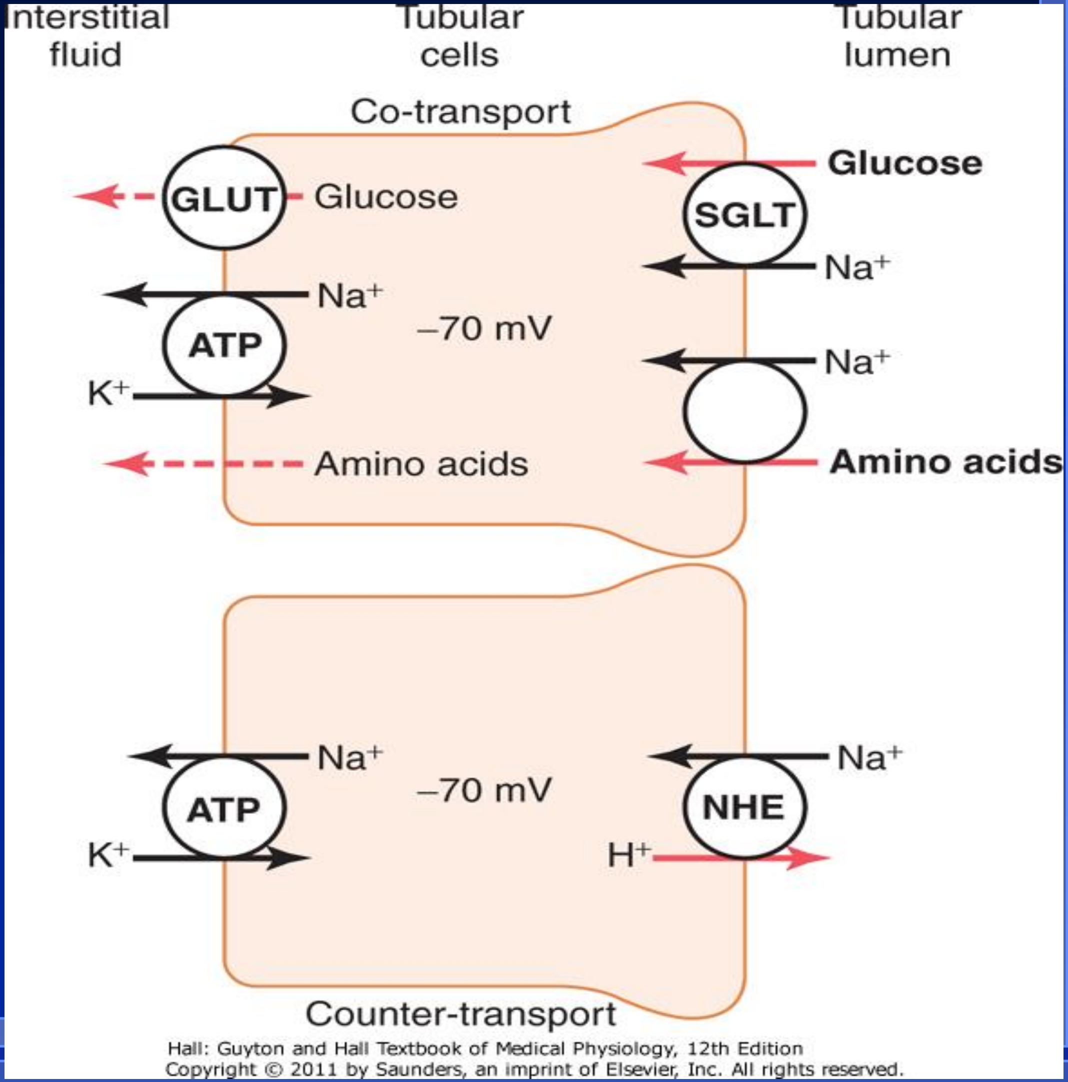
- **Active Transport**

- **Primary Active Transport Through the Tubular Membrane Is Linked to Hydrolysis of ATP**

Basic mechanism for active transport of Na^+ through the tubular epithelial cell



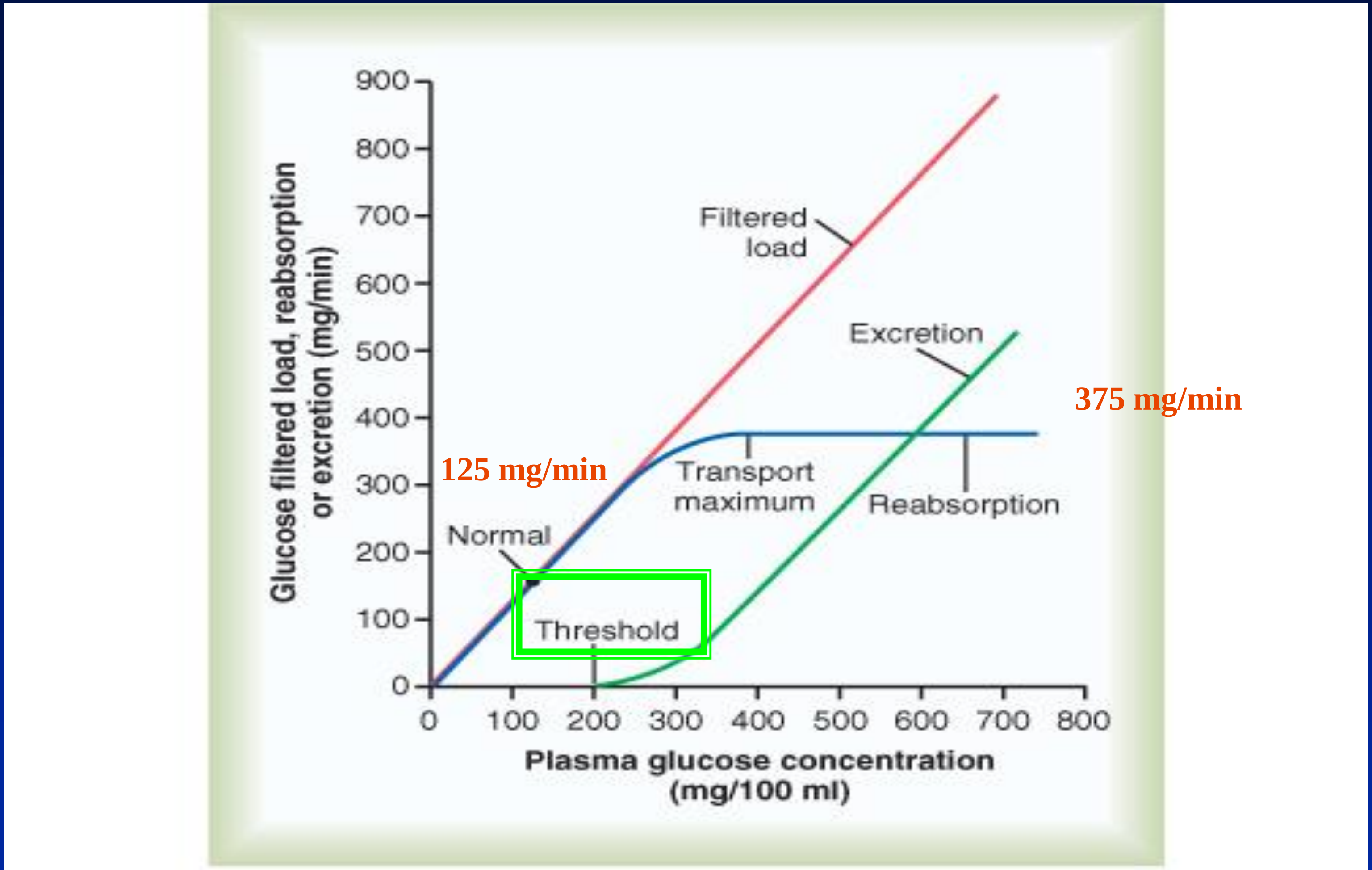
Mechanisms of <u>secondary active transport</u> for glucose and amino acids



<u>Secondary Active Secretion</u> into the Tubules

- Pinocytosis—An <u>Active Transport Mechanism</u> for Reabsorption of Proteins
- Transport Maximum for Substances That Are Actively Reabsorbed

Relations among the filtered load, reabsorption and excretion of glucose



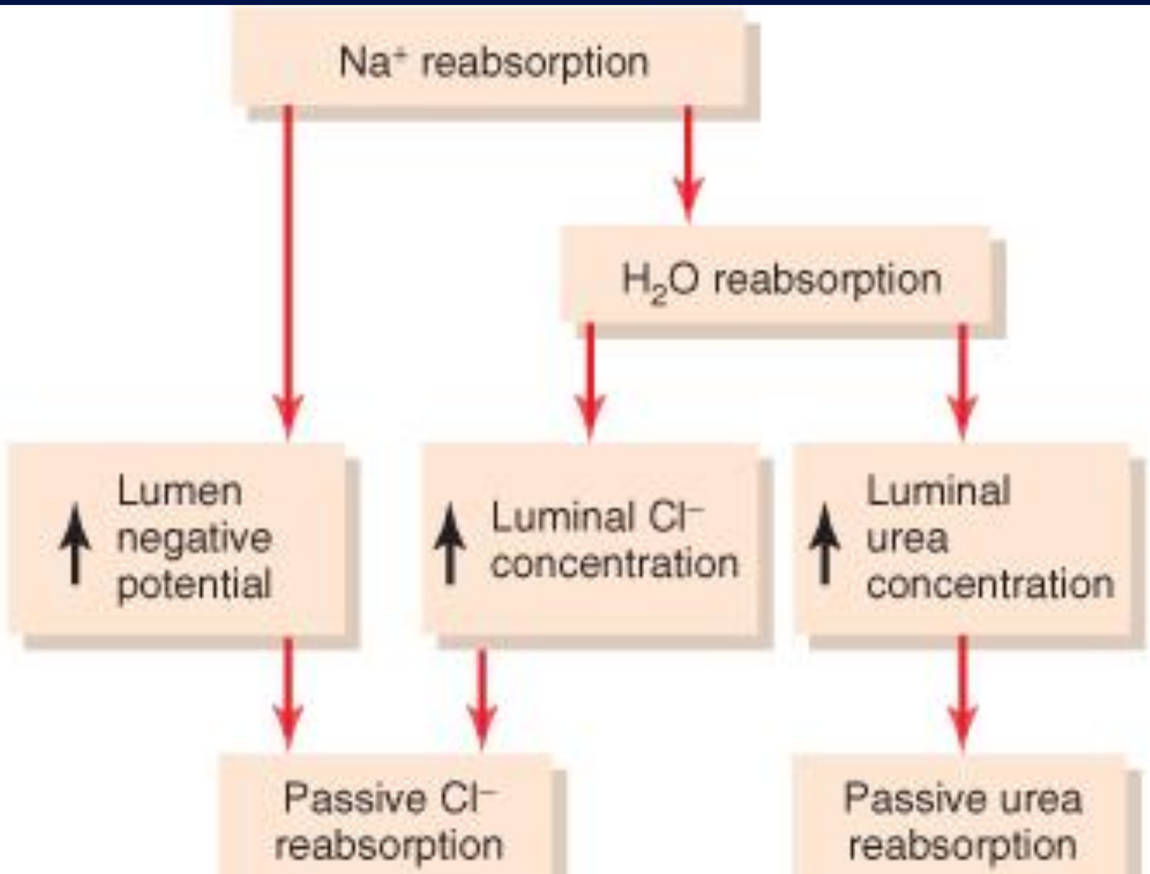
- **Substances That Are Actively Transported but Do Not Exhibit a Transport Maximum**

- gradient-time transport

- **Passive Water Reabsorption by Osmosis Is Coupled Mainly to Sodium Reabsorption**

- **Reabsorption of Chloride, Urea, and Other Solutes by Passive Diffusion**

Mechanisms by which water, Cl^-, and urea reabsorption are coupled with Na^+ reabsorption



Secondary Active transport of Cl^-

Reabsorption and Secretion Along Different Parts of the Nephron

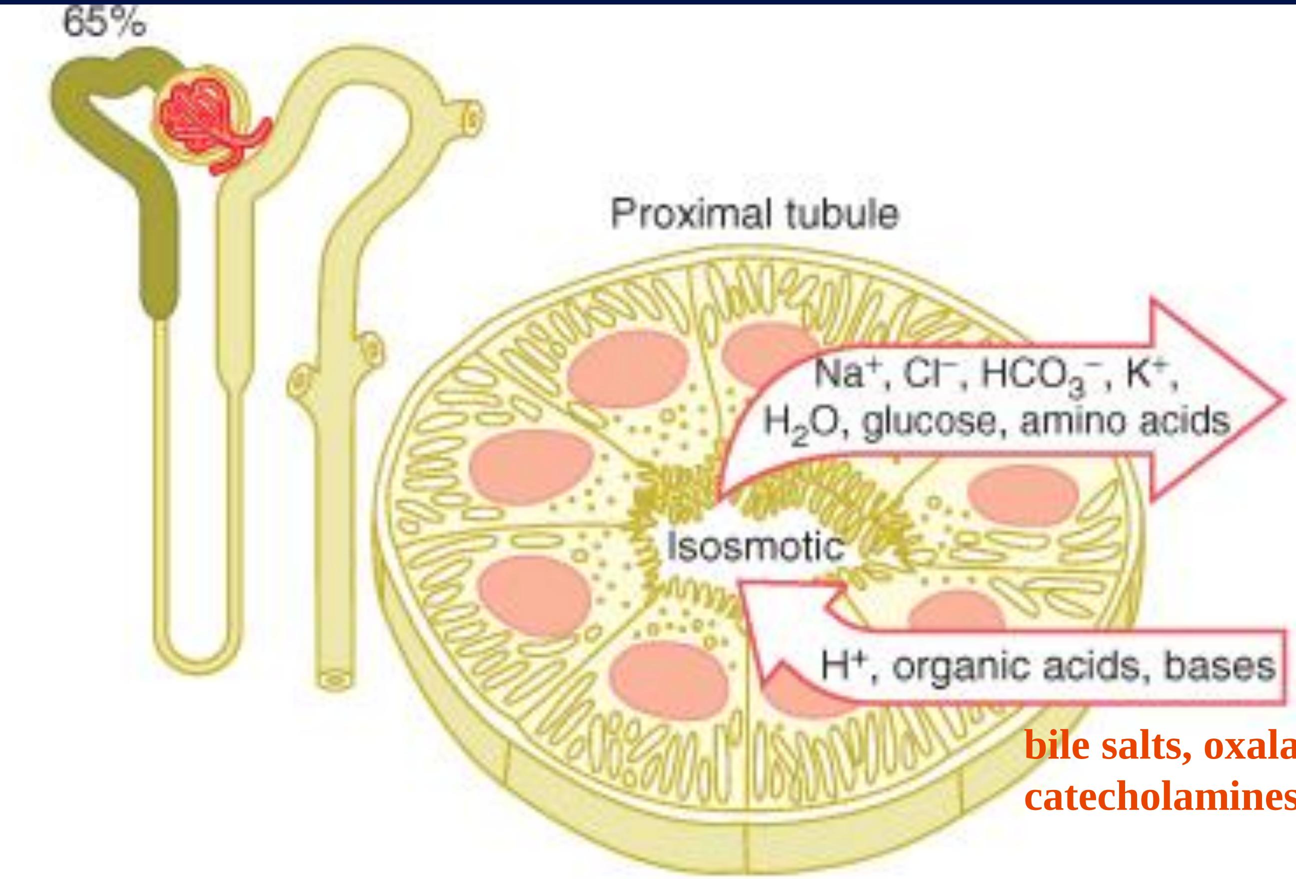
- Proximal Tubular Reabsorption (65%)

1- Proximal Tubules Have a High Capacity for Active and Passive Reabsorption

- First half of PT
- Second half of PT

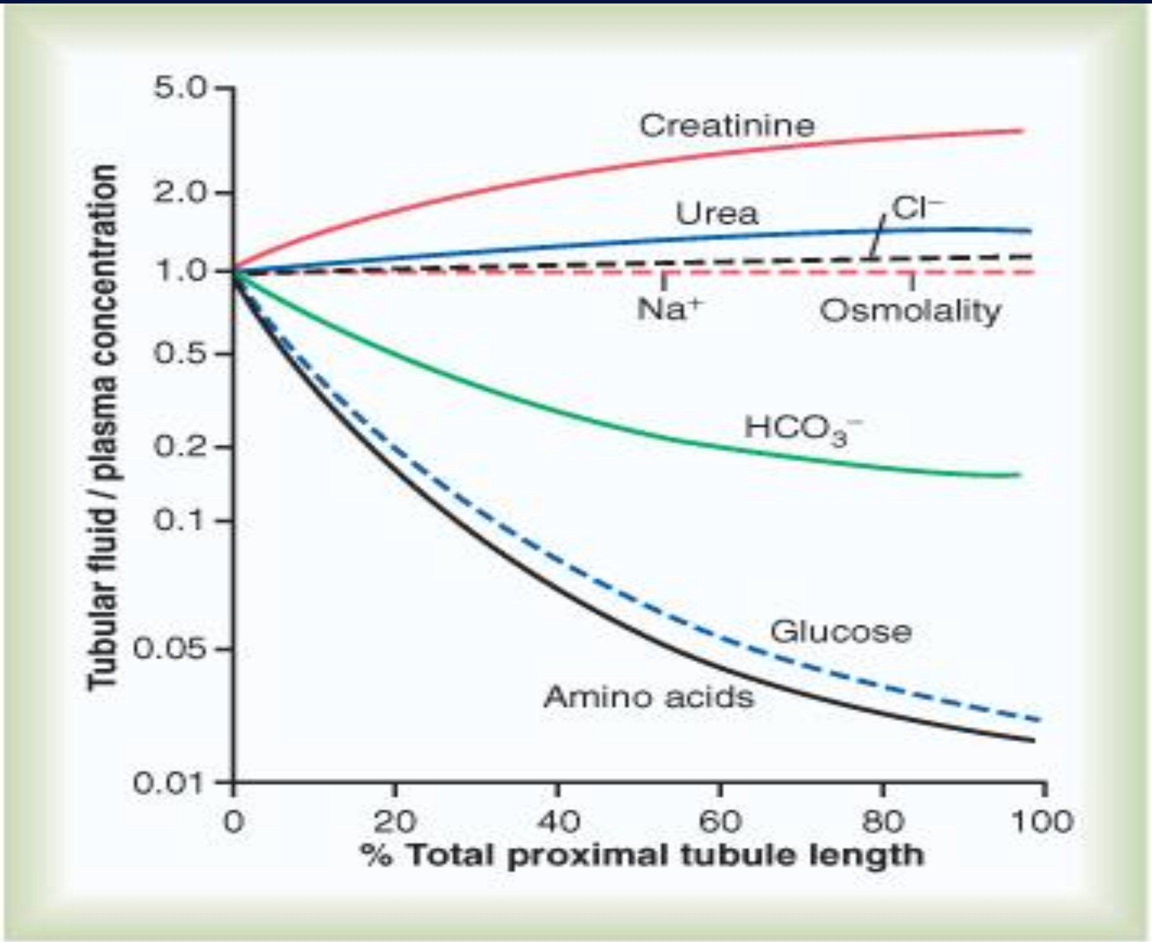
2- Secretion of Organic Acids and Bases by the Proximal Tubule

Characteristics of proximal tubule in solute reabsorption and secretion

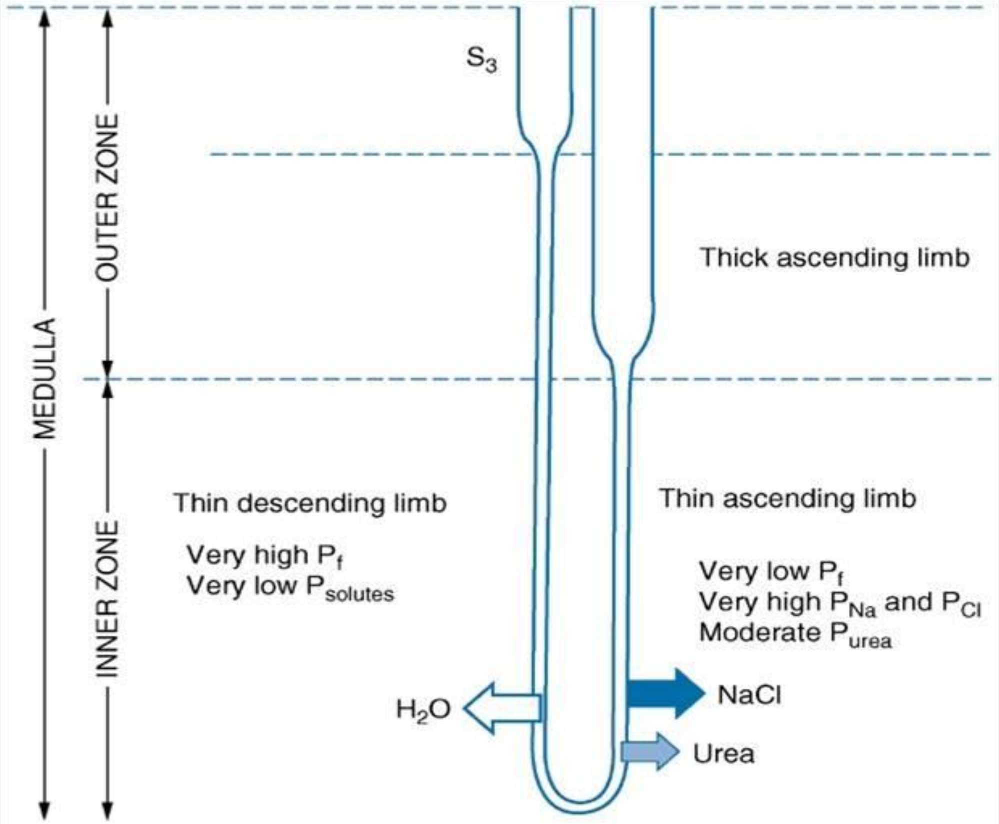


bile salts, oxalate, urate, catecholamines and PAH

Changes in concentration of tubular solutes along PT relative to plasma

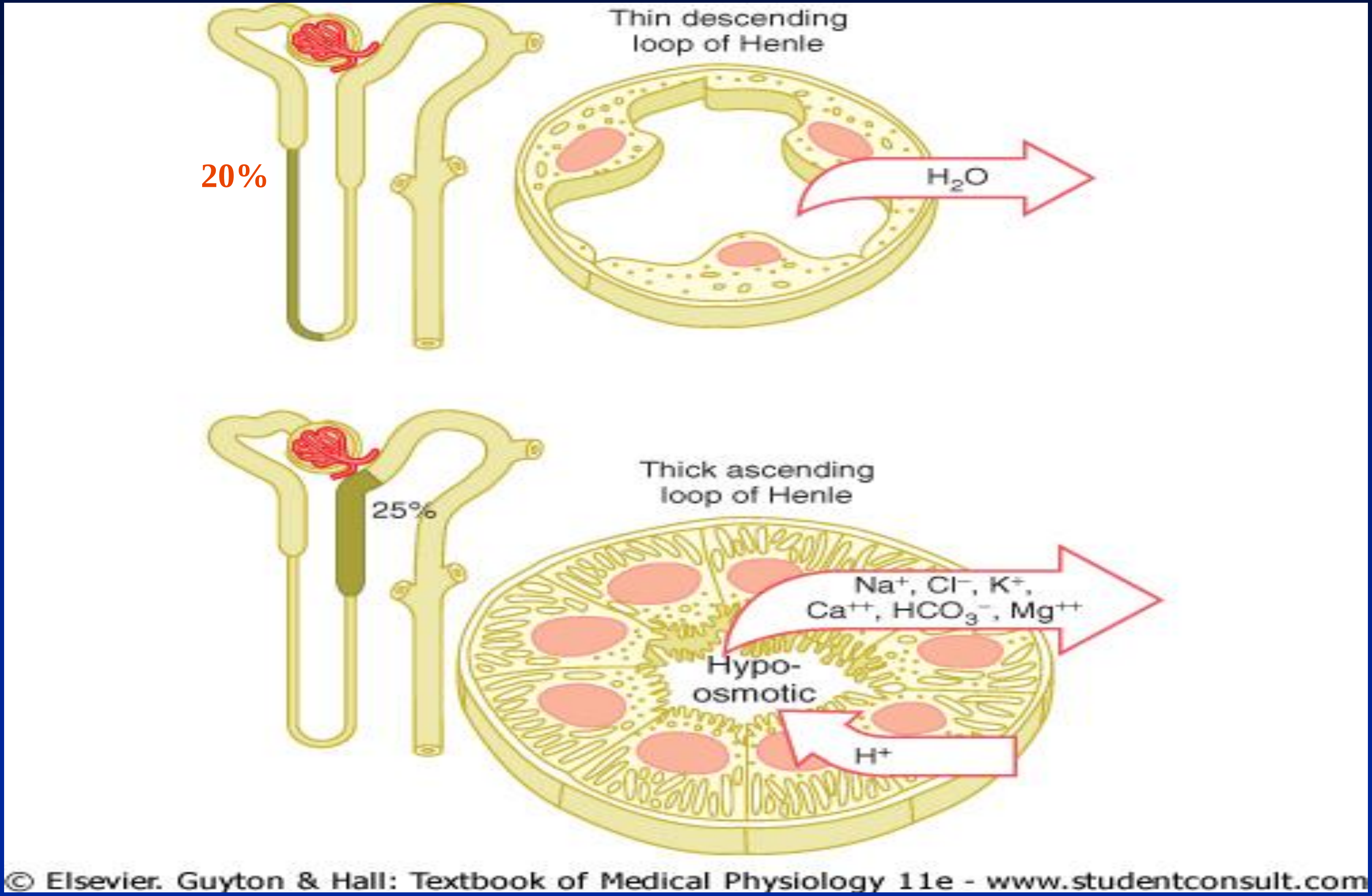


Solute and Water Transport in the <u>Loop of Henle</u>

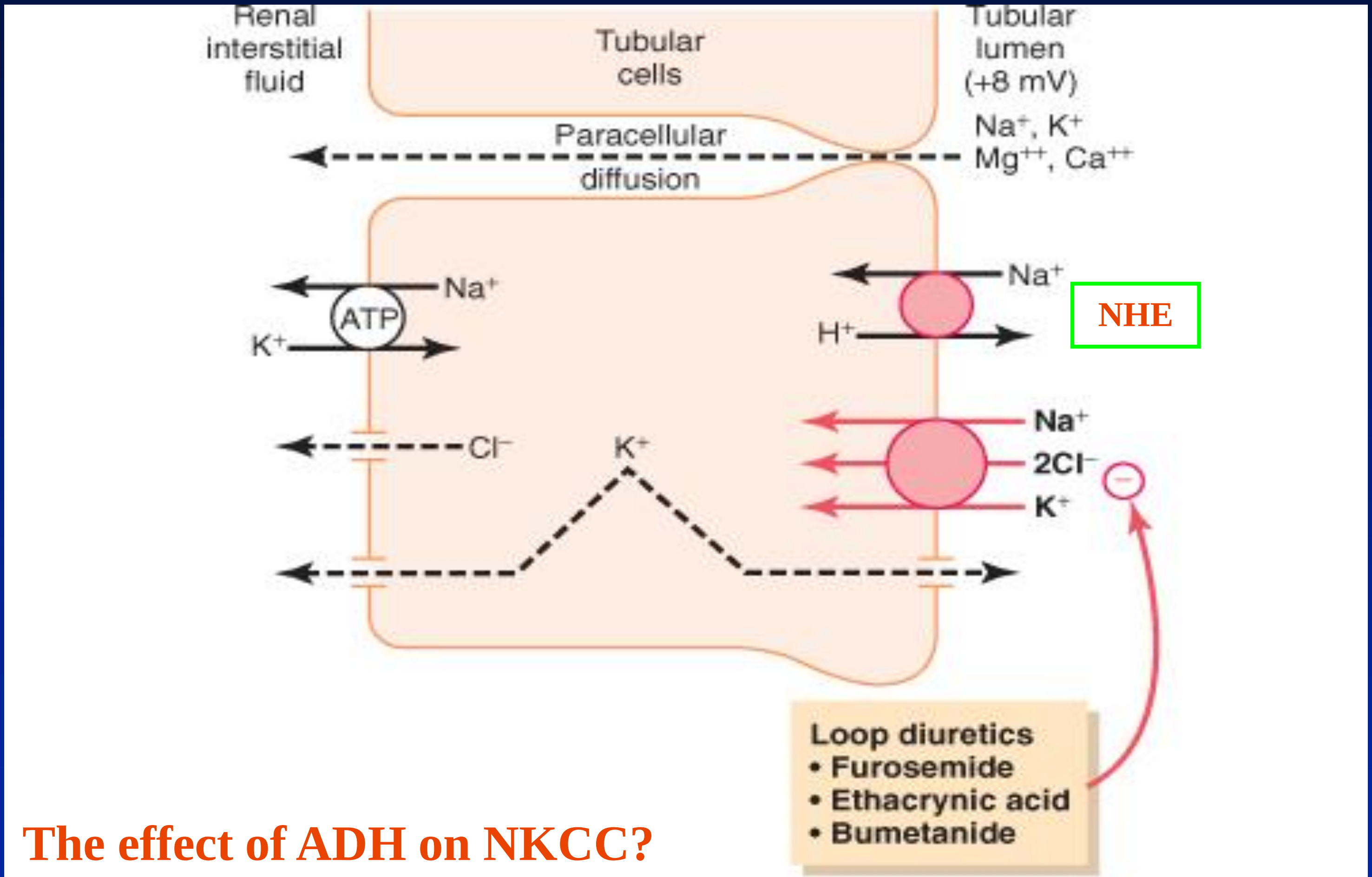


(Modified from Brenner BM, Coe FL, Rector FC Jr: Renal Physiology in Health and Disease. Philadelphia, WB Saunders, 1987, p 39.)

The properties of thin descending and thick ascending segments of the loop of henle



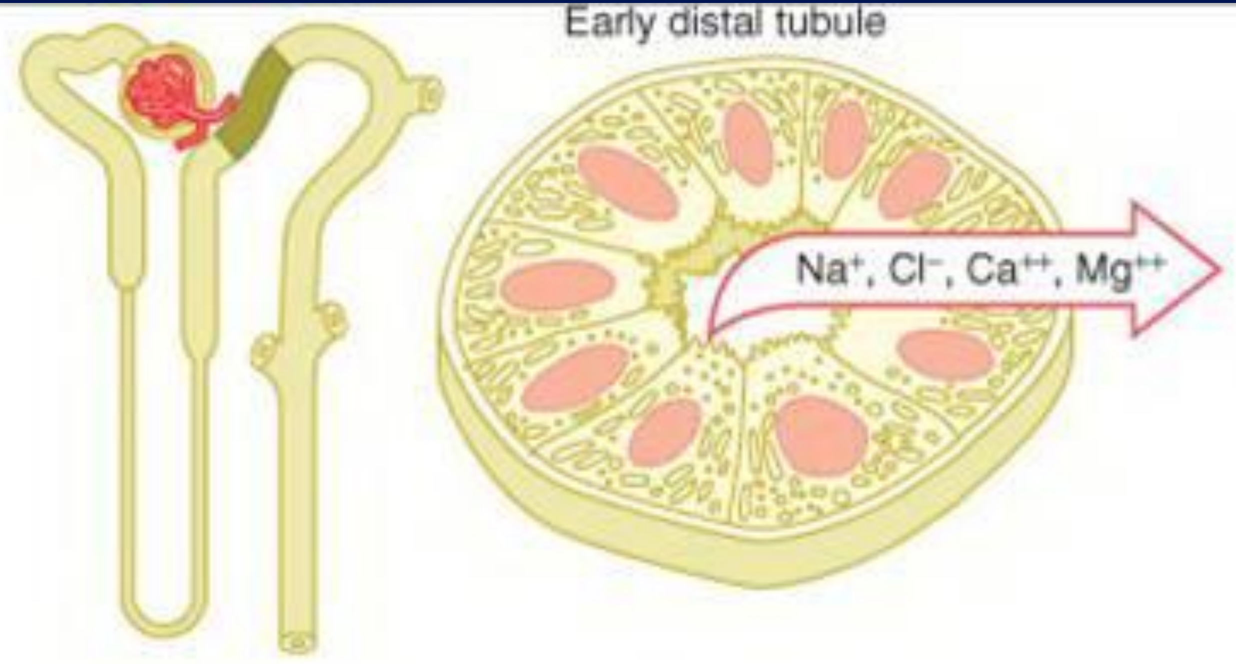
Mechanisms of sodium, chloride, and potassium transport in the thick ascending loop of henle



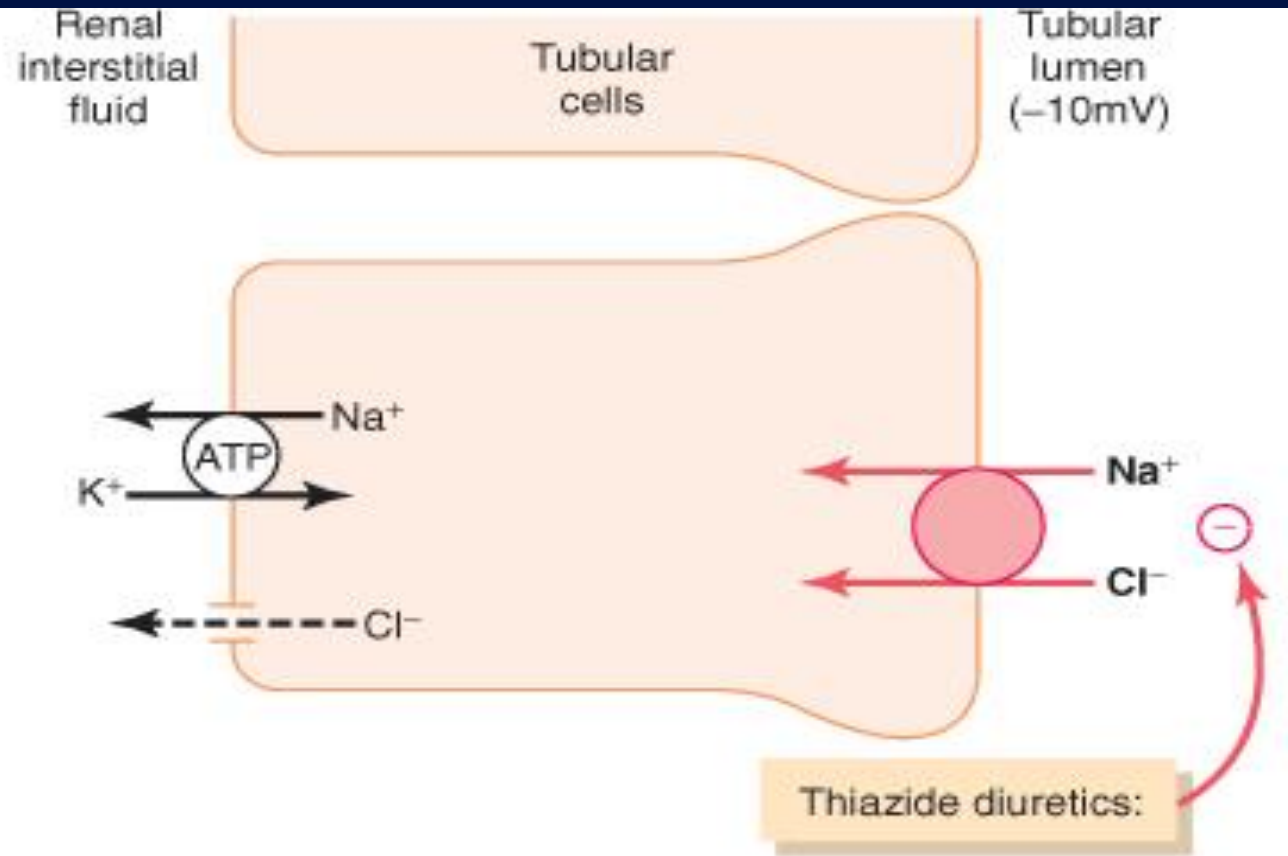
The effect of ADH on NKCC?

Distal Tubule

5% NaCl

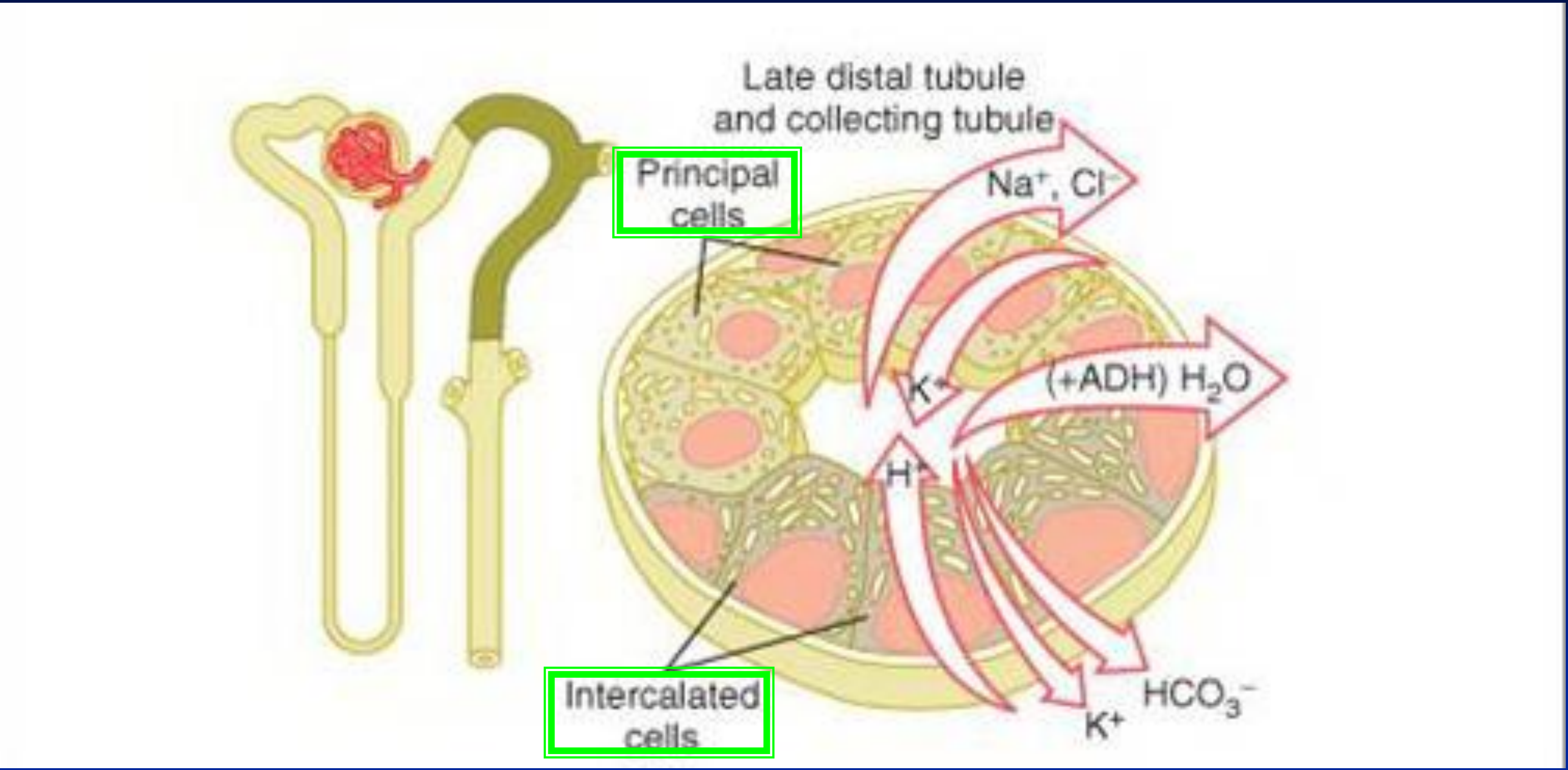


Mechanisms of sodium chloride transport in the early distal tubule (5%)



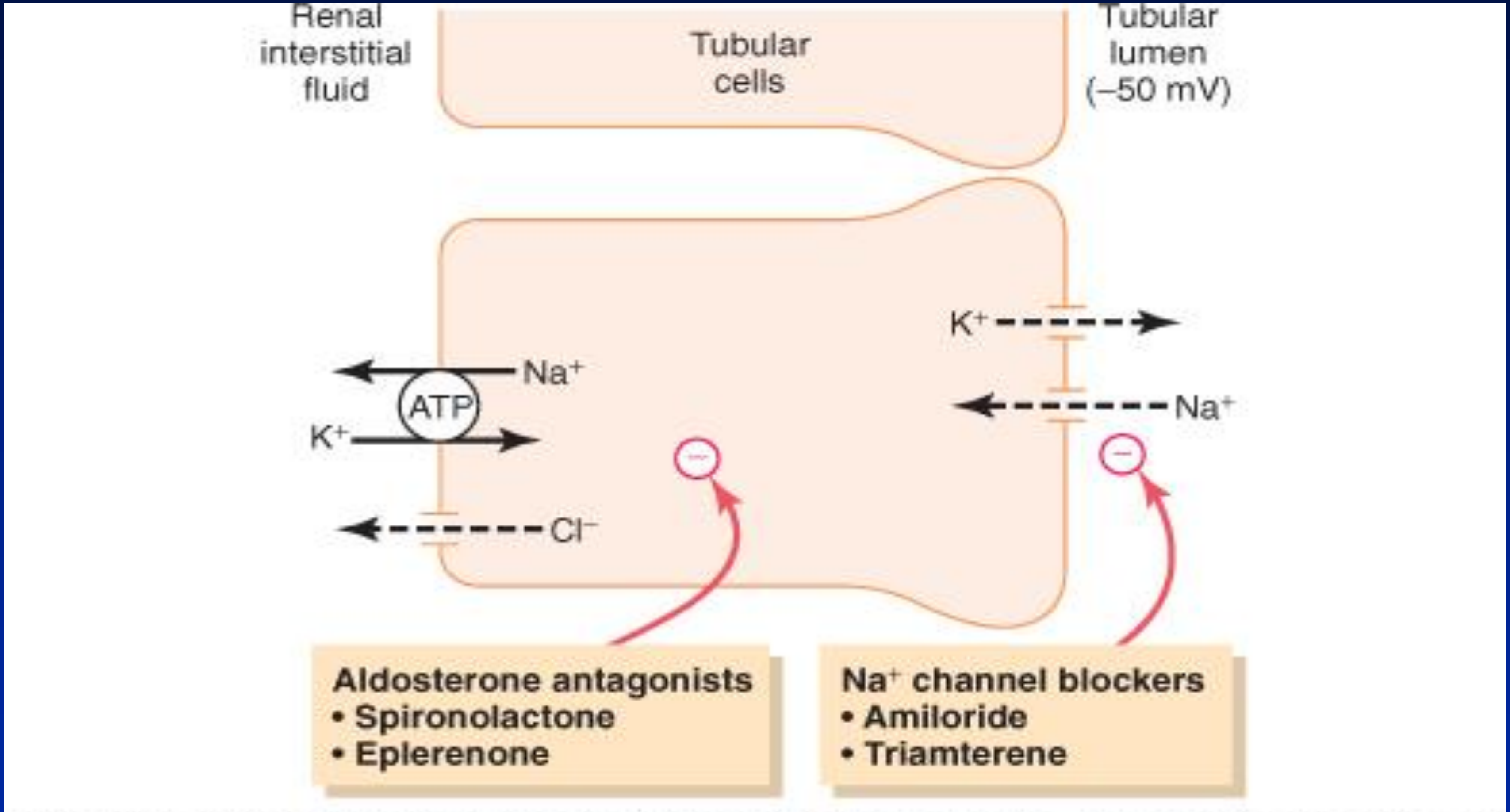
Diluting segment

Transport characteristics of the late distal tubule and collecting tubule

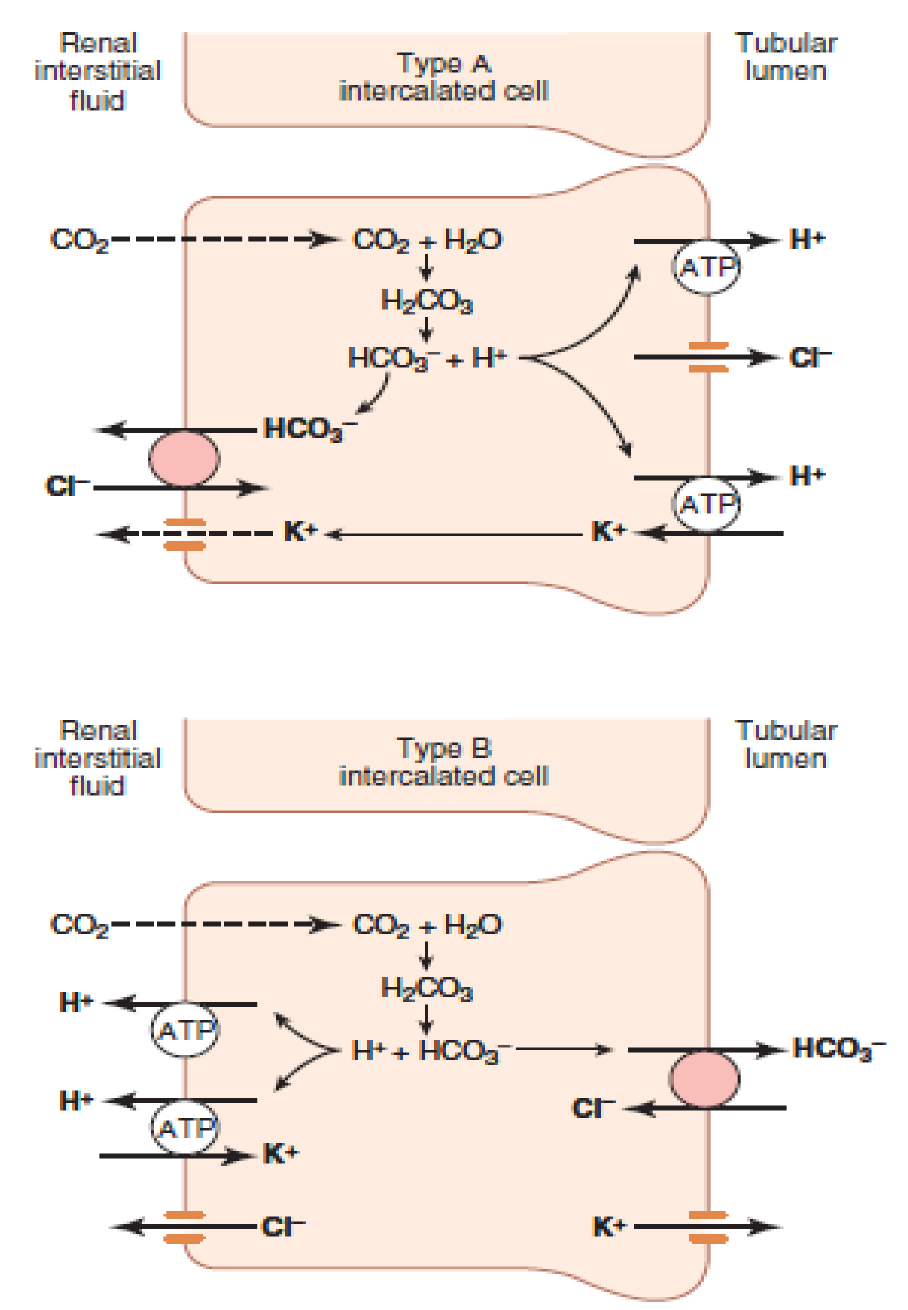


The effect of ADH on LDT and CCT?

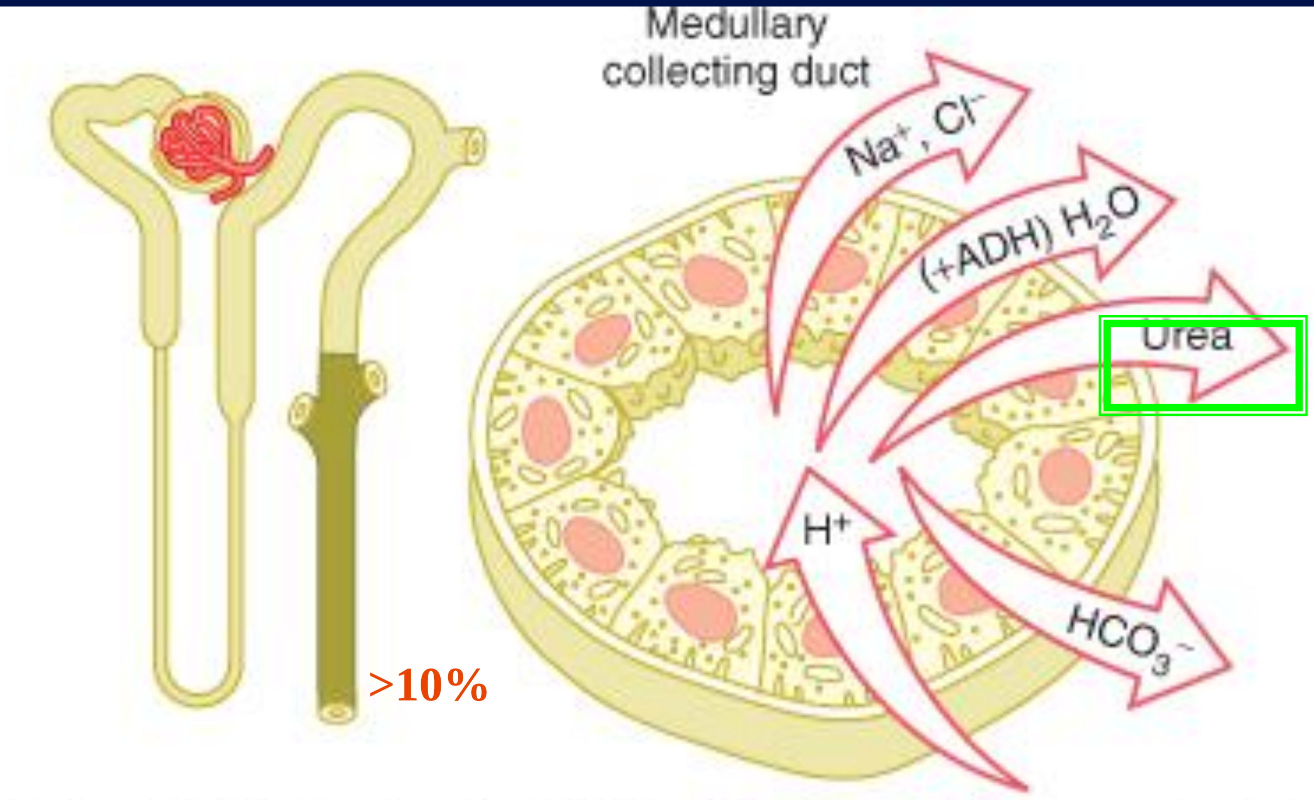
Principal Cells Reabsorb Sodium and Secrete Potassium (LDT & CCD)



Type A and type B intercalated cells of the collecting tubule

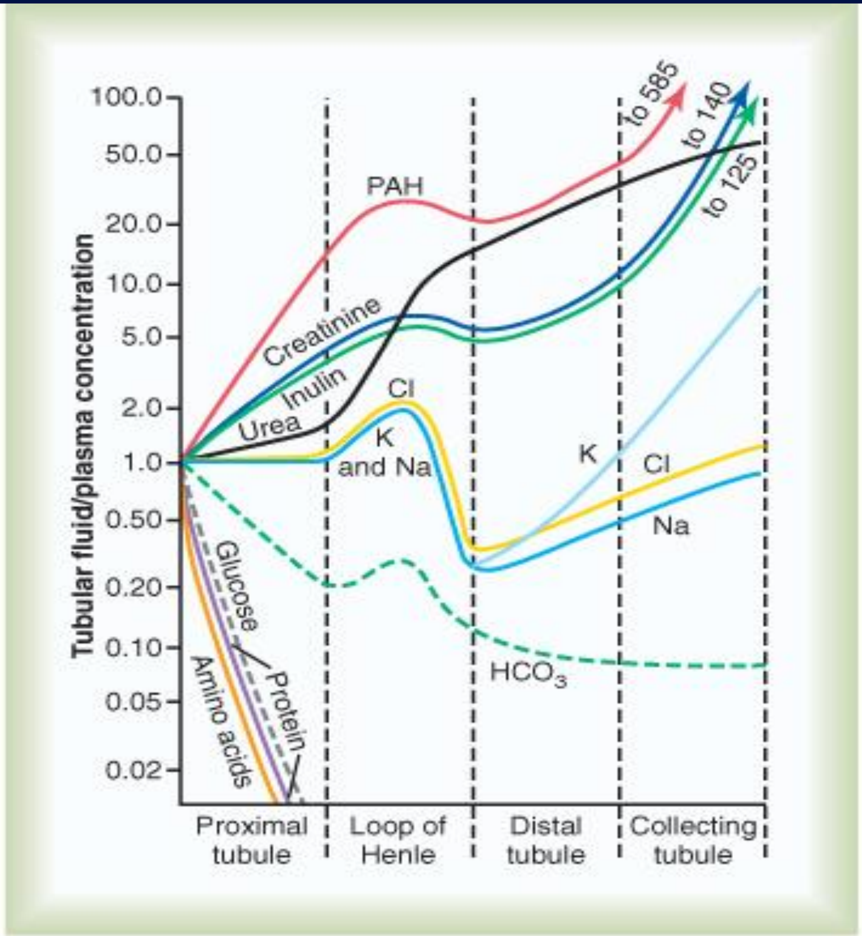


Transport characteristics of the medullary collecting duct



The effect of ADH on IMCD?

Changes in concentration of different substances at different points of tubular system relative to plasma



- **Tubular Fluid /Plasma Inulin Concentration Ratio Can Be Used to Measure Water Reabsorption by the Renal Tubules**

Regulation of Tubular Reabsorption

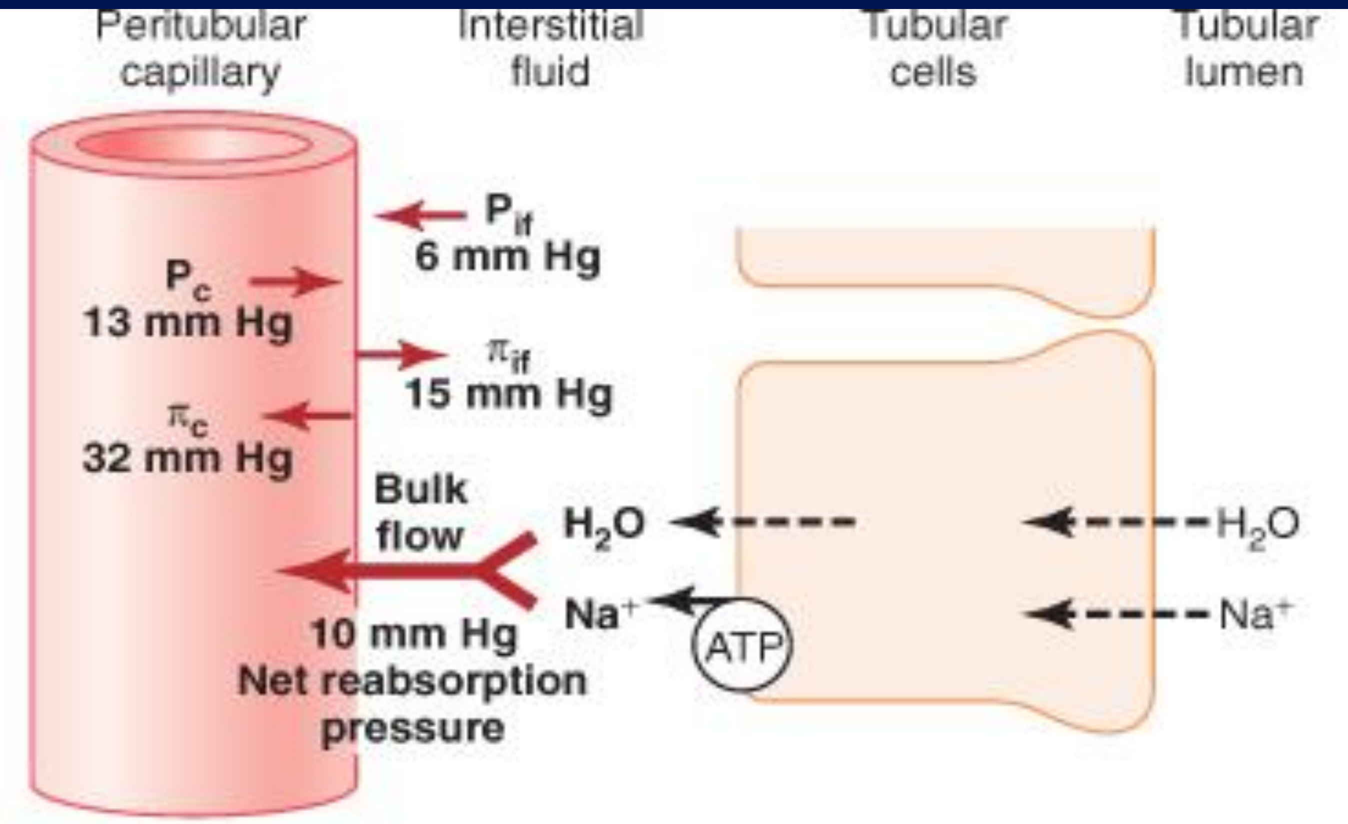
- 1- Glomerulotubular Balance—The Ability of the Tubules to Increase Reabsorption Rate in Response to Increased Tubular Load

2- Peritubular Capillary and Renal Interstitial Fluid Physical Forces

- Normal Values for Physical Forces and Reabsorption Rate (124 ml/min)

$$\text{Reabsorption} = K_f \times \text{Net reabsorptive force}$$

Summary of the hydrostatic and colloid osmotic forces that determine fluid reabsorption in peritubular capillaries



- **Regulation of Peritubular Capillary Physical Forces**

- The peritubular capillary hydrostatic pressure

- colloid osmotic pressures of the peritubular capillaries

- Changes in the peritubular capillary K_f

Factors That Can Influence Peritubular Capillary Reabsorption

↑ P_c → ↓ Reabsorption

- ↓ R_A → ↑ P_c
- ↓ R_E → ↑ P_c
- ↑ Arterial Pressure → ↑ P_c

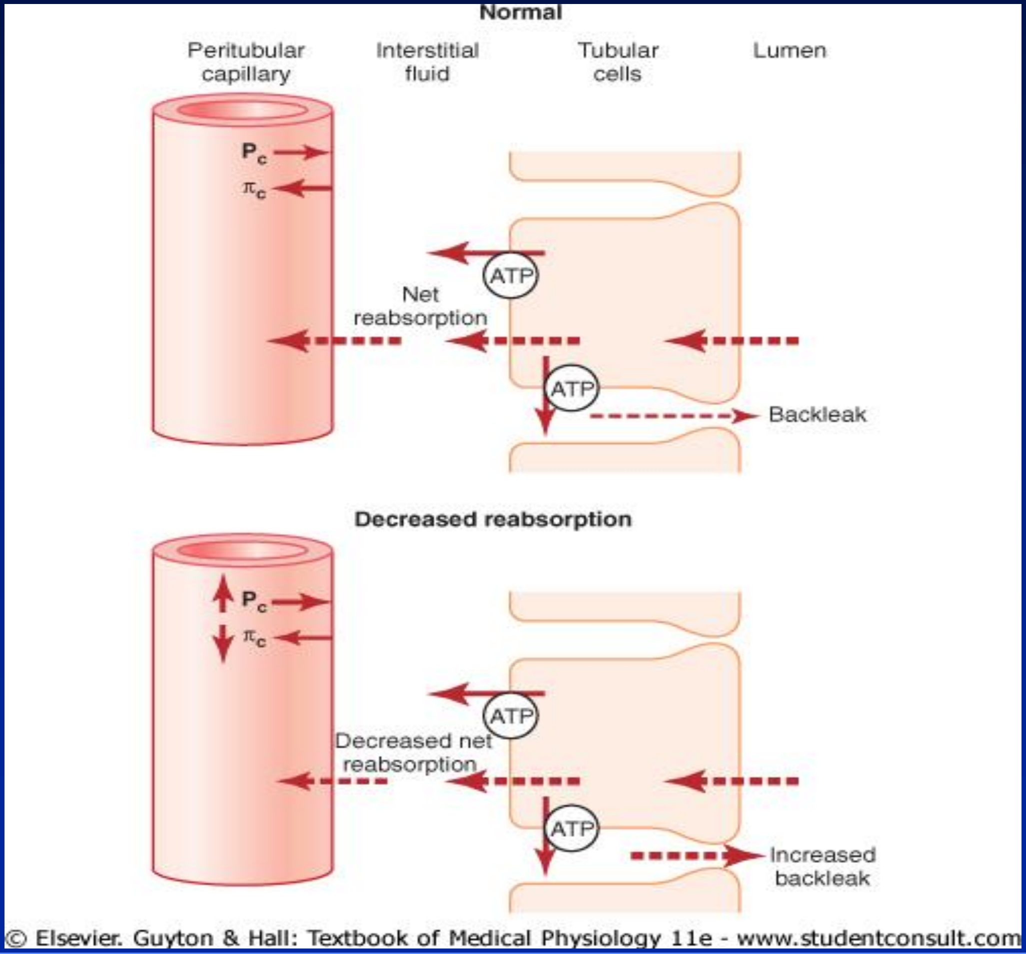
↑ π_c → ↑ Reabsorption

- ↑ π_A → ↑ π_c
- ↑ FF → ↑ π_c

↑ K_f → ↑ Reabsorption

- **Renal Interstitial Hydrostatic and Colloid Osmotic Pressures**

Proximal tubular and peritubular capillary reabsorption under normal condition (top) and decreased peritubular capillary reabsorption (bottom)



Effect of Arterial Pressure on Urine Output—The Pressure-Natriuresis and Diuresis Mechanisms

1. Increased arterial pressure → ↑GFR → ↑ urine output

2. Increased arterial pressure → ↑peritubular hyd. Pressure →↓tubular reabsorption

3. Increased arterial pressure → ↓Ang II formation & Aldosterone → ↓reabsorption

4. Increased arterial pressure → internalization of sodium transporter proteins from the apical membranes to the cytoplasm → ↓reabsorption

3- Hormonal Control of Tubular Reabsorption

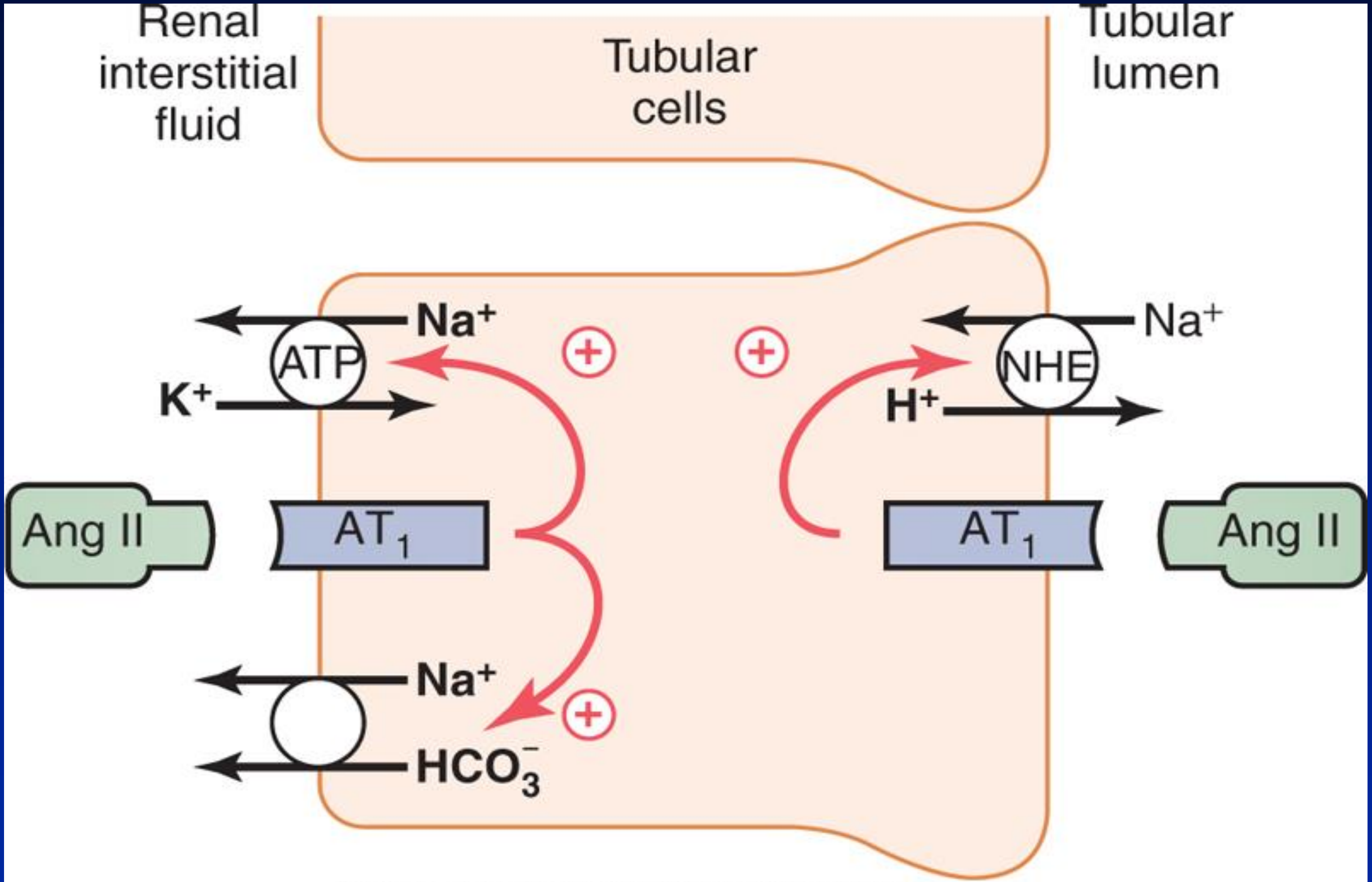
Hormone	Site of Action	Effects
Aldosterone	Collecting tubule and duct	↑ NaCl, H_2O reabsorption, ↑ K^+ secretion
Angiotensin II	Proximal tubule, thick ascending loop of Henle/distal tubule, collecting tubule	↑ NaCl, H_2O reabsorption, ↑ H^+ secretion
Antidiuretic hormone	Distal tubule/collecting tubule and duct	↑ H_2O reabsorption
Atrial natriuretic peptide	Distal tubule/collecting tubule and duct	↓ NaCl reabsorption
Parathyroid hormone	Proximal tubule, thick ascending loop of Henle/distal tubule	↓ PO_4^{---} reabsorption, ↑ Ca^{++} reabsorption

- Aldosterone Increases Sodium Reabsorption and Increases Potassium Secretion (Principal cells)

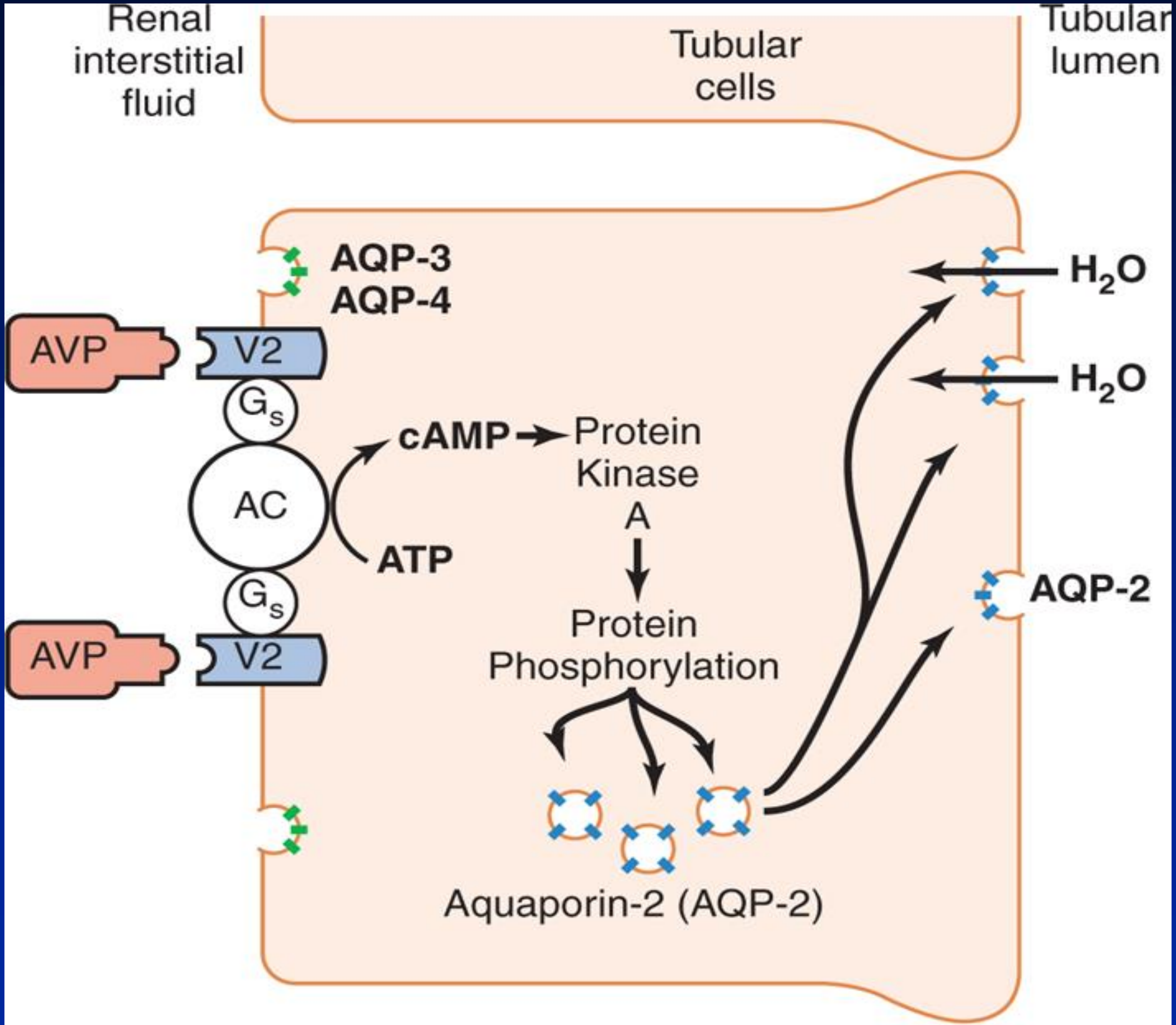
Angiotensin II Increases Sodium and Water Reabsorption (the body's most powerful sodium-retaining hormone)

- Angiotensin II stimulates aldosterone secretion
- Angiotensin II constricts the efferent arterioles
- Angiotensin II directly stimulates sodium reabsorption in the PT, the loops of Henle, DT, and CT

Direct effect of Angiotensin II



ADH Increases Water Reabsorption



Hall: Guyton and Hall Textbook of Medical Physiology, 12th Edition

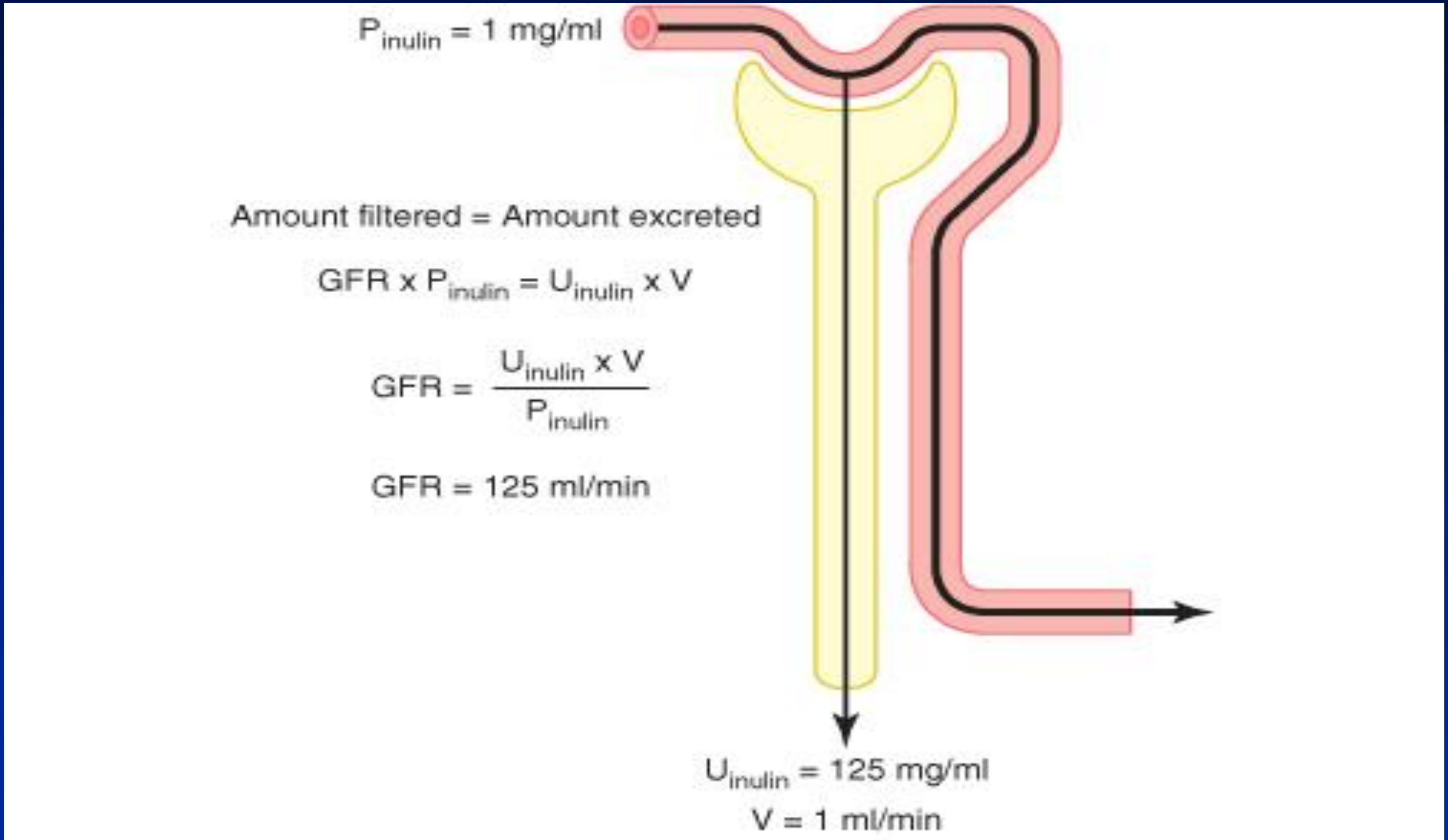
- Atrial Natriuretic Peptide Decreases Sodium and Water Reabsorption (CD)
- Parathyroid Hormone Increases Calcium Reabsorption (DT)
- Sympathetic Nervous System Activation Increases Sodium Reabsorption

(decrease GFR, increase Na^+ reabsorption & increase renin release)

Use of Clearance Methods to Quantify Kidney Function

Term	Equation	Units
Clearance rate (C_x)	$C_x = \frac{U_x \times V}{P_x}$	ml/min
Glomerular filtration rate (GFR)	$GFR = \frac{U_{inulin} \times V}{P_{inulin}}$	
Clearance ratio	$\text{Clearance ratio} = \frac{C_x}{C_{inulin}}$	None
Effective renal plasma flow (ERPF)	$ERPF = C_{PAH} = \frac{U_{PAH} \times V}{P_{PAH}}$	ml/min
Renal plasma flow (RPF)	$RPF = \frac{C_{PAH}}{E_{PAH}} = \frac{(U_{PAH} \times V/P_{PAH})}{(P_{PAH} - V_{PAH})/P_{PAH}} = \frac{U_{PAH} \times V_{PAH}}{P_{PAH} - V_{PAH}}$	ml/min
Renal blood flow (RBF)	$RBF = \frac{RPF}{1 - \text{Hematocrit}}$	ml/min
Excretion rate	$\text{Excretion rate} = U_x \times V$	mg/min, mmol/min, or mEq/min
Reabsorption rate	$\text{Reabsorption rate} = \text{Filtered load} - \text{Excretion rate} = (GFR \times P_x) - (U_x \times V)$	mg/min, mmol/min, or mEq/min
Secretion rate	$\text{Secretion rate} = \text{Excretion rate} - \text{Filtered load}$	mg/min, mmol/min, or mEq/min

Measurement of GFR from the renal clearance of inulin



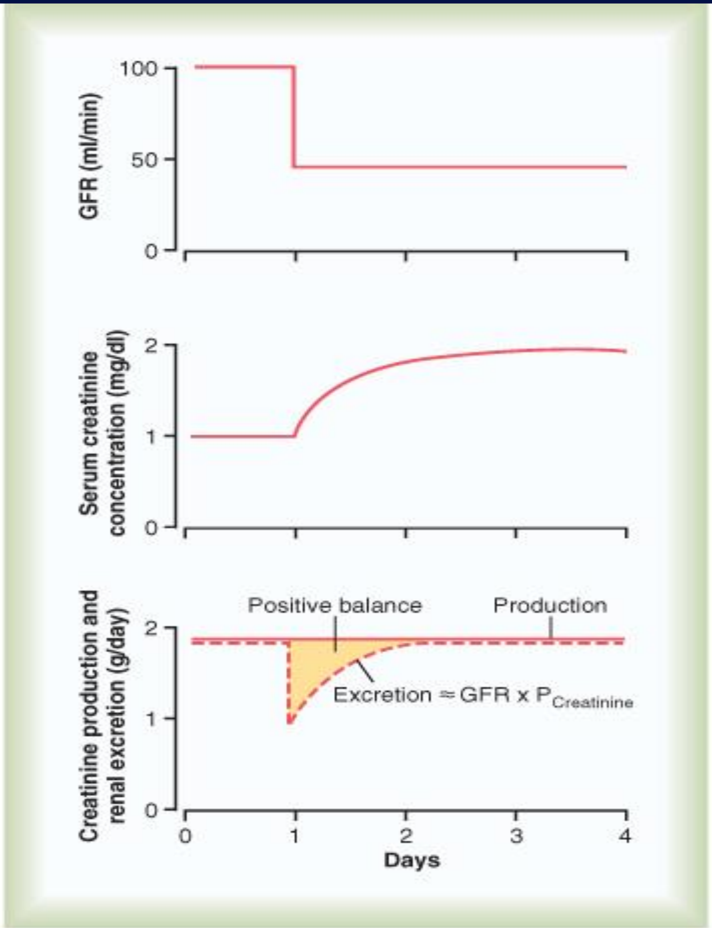
PAH Clearance Can Be Used to Estimate Renal Plasma Flow

Renal delivery = Urinary excretion

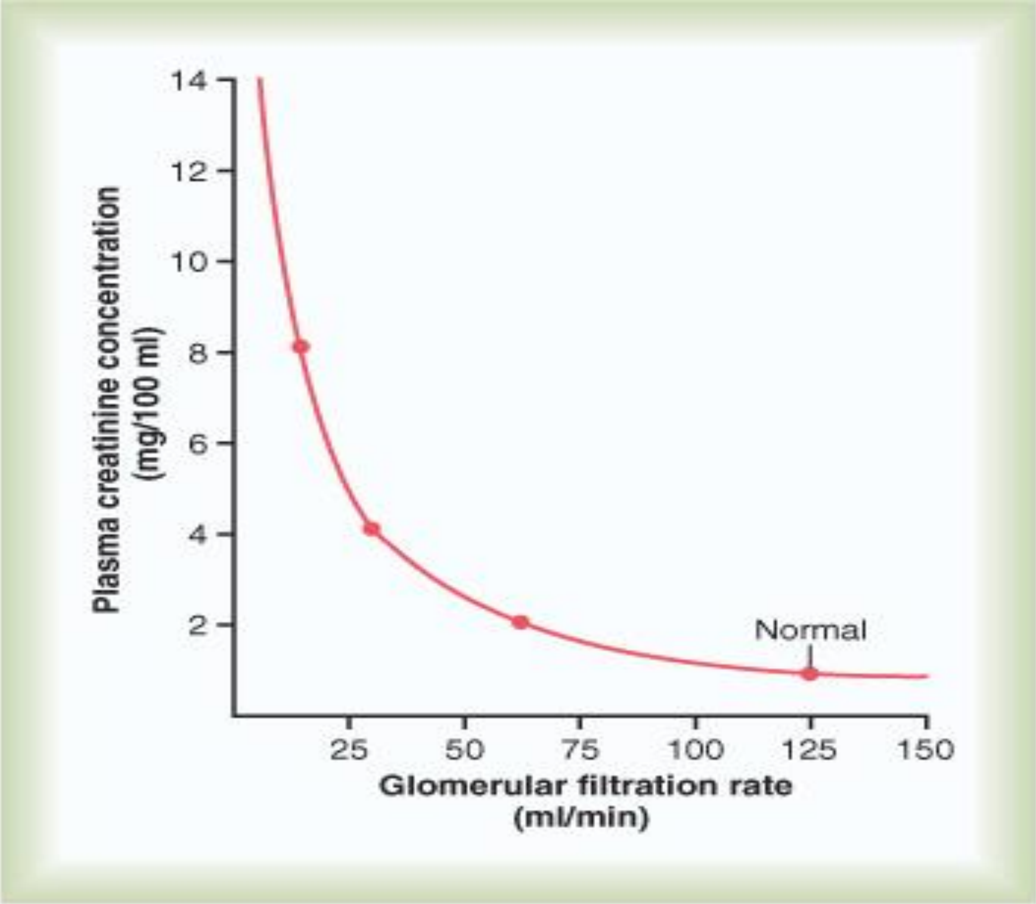
$$RPF \times P_{PAH} = U_{PAH} \times V^{o} \longrightarrow RPF = \frac{U_{PAH} \times V^{o}}{P_{PAH}}$$

- **Creatinine Clearance and Plasma Creatinine Concentration Can Be Used to Estimate GFR**

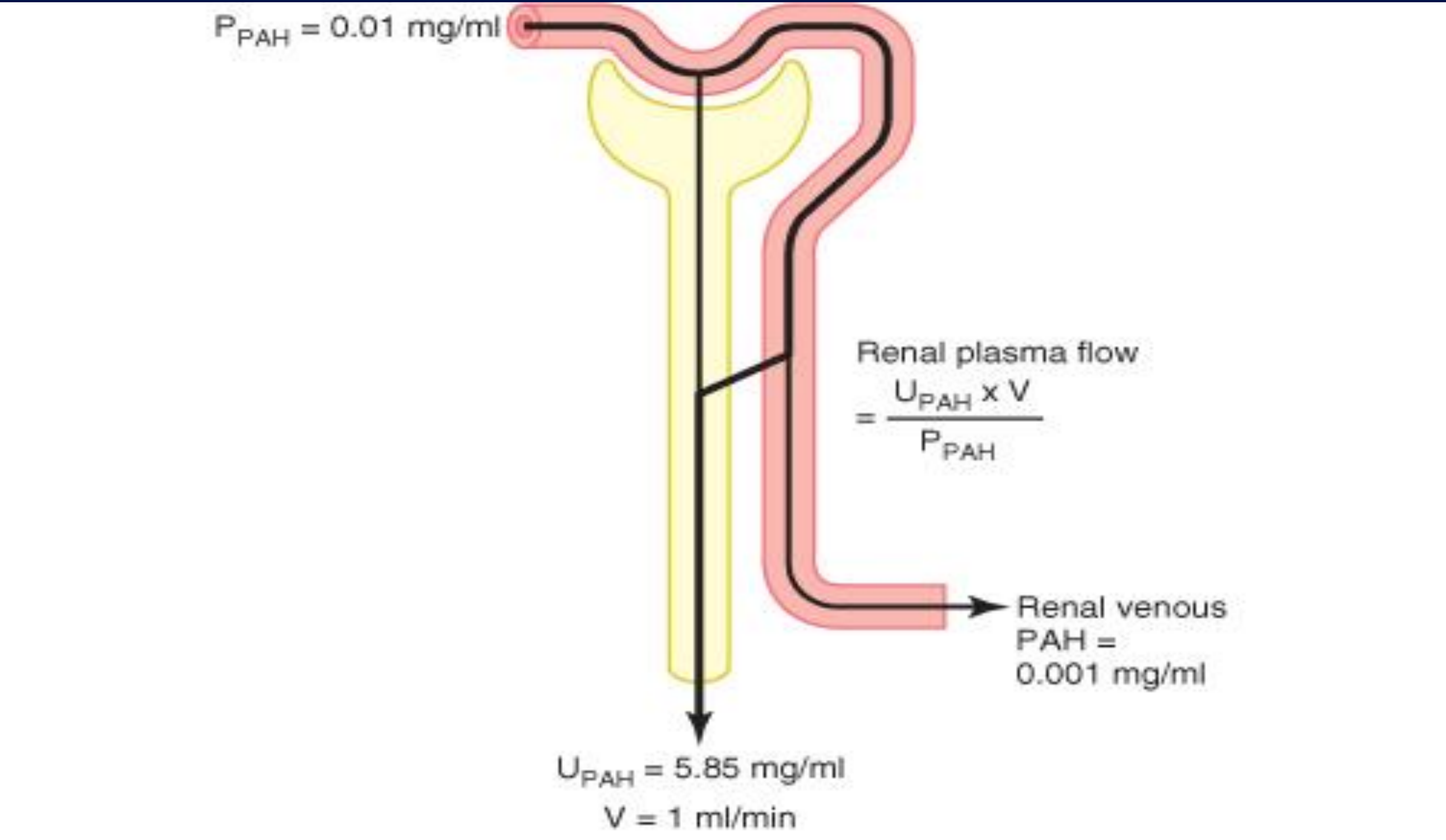
Effect of reducing GFR by 50 per cent on serum Cr and on Cr excretion rate when the production rate of Cr remains constant



Approximate relationship between GFR and plasma creatinine concentration under steady-state conditions



Measurement of renal plasma flow from the renal clearance of PAH



- **Filtration Fraction Is Calculated from GFR Divided by Renal Plasma Flow**
- **Calculation of Tubular Reabsorption or Secretion from Renal Clearances**
- **Comparisons of Inulin Clearance with Clearances of Different Solutes**

Comparisons of Inulin Clearance with Clearances of Different Solutes

Substance	Clearance Rate (ml/min)
Glucose	0
Sodium	0.9
Chloride	1.3
Potassium	12.0
Phosphate	25.0
Inulin	125.0
Creatinine	140.0


Thanks for your attention

Intercalated Cells Avidly Secrete Hydrogen and Reabsorb Bicarbonate and Potassium Ions