Urinary System: Renal Physiology for Medical Students, L4-8

Urine Formation by the Kidneys:
II. Tubular Reabsorption and Secretion

Reference: Guyton & Hall, Jordanian first edition
Chapter27

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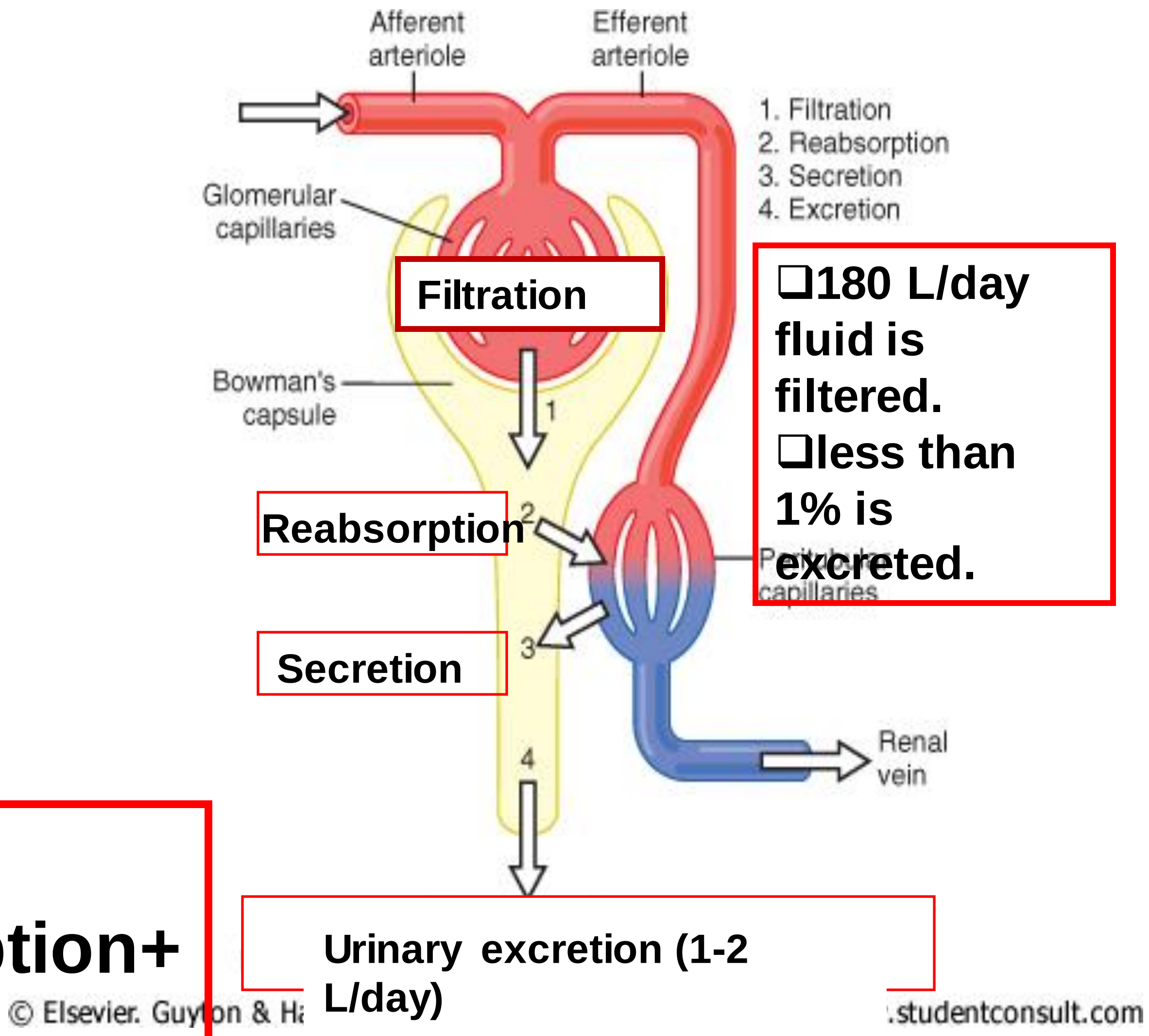
Objectives

- Describe the mechanisms of renal reabsorption and secretion in the nephron for different substances.
- Identify the functions of the different parts of the nephron tubules and describe the transport mechanisms occurring in each part.
- Describe the changes in concentrations of different substances in the renal tubules and the underlying causes of these changes.
- Understand how inulin can be used to estimate water reabsorption in each segment of the nephron.

The functional unit of the kidney

Basic Mechanisms of Urine Formation

- Ultrafiltration
- Reabsorption
- Secretion
- Excretion



Filtration

Reabsorption

Secretion

❑180 L/day fluid is filtered.
❑less than 1% is excreted.

Urinary excretion (1-2 L/day)

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Excretion= Filtration-Reabsorption+ Secretion

Audio-Visual Aid

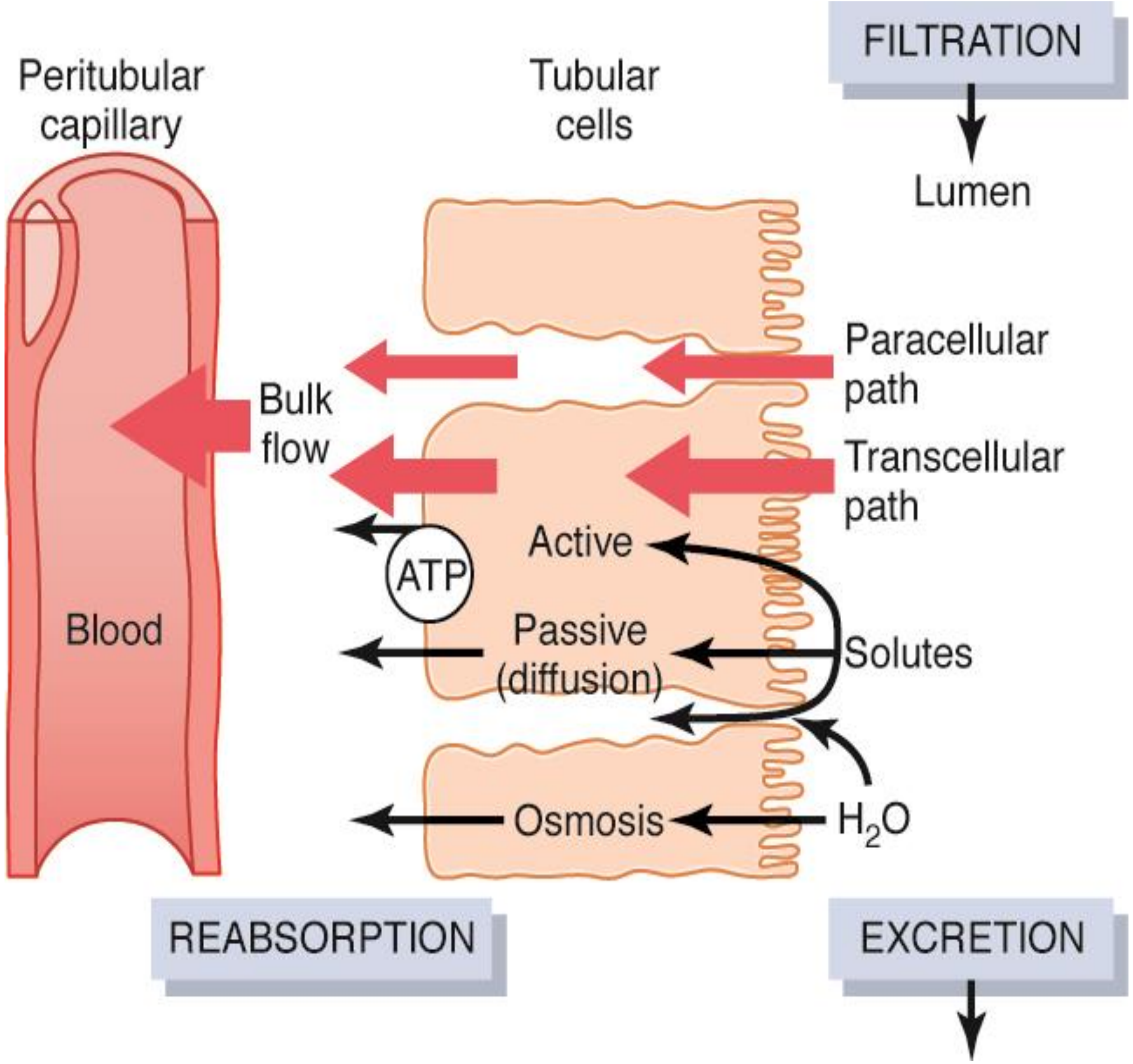
Please watch this animation Demonstarting:

- [Reabsorption and Secretion animation - YouTube]

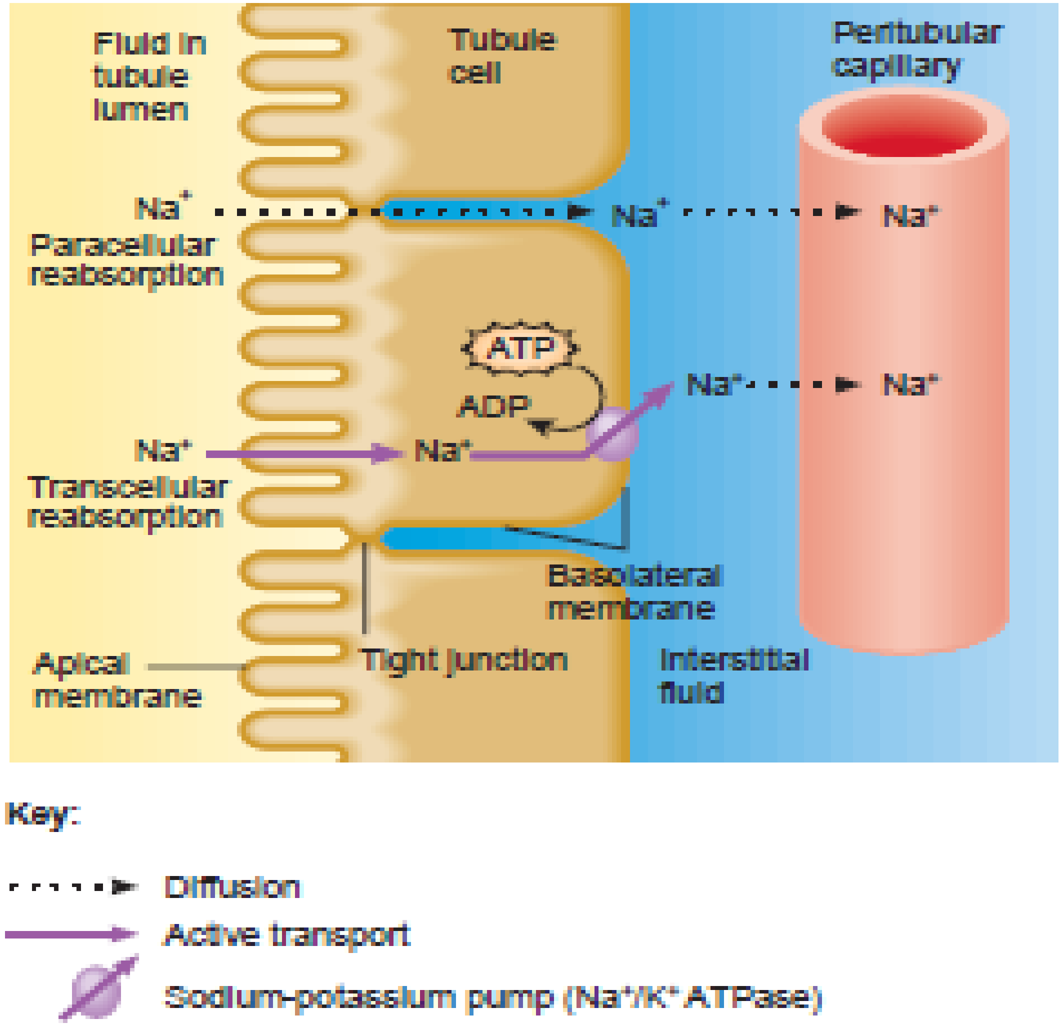
Reabsorption and Secretion animation

medical amboss
2.18K subscribers

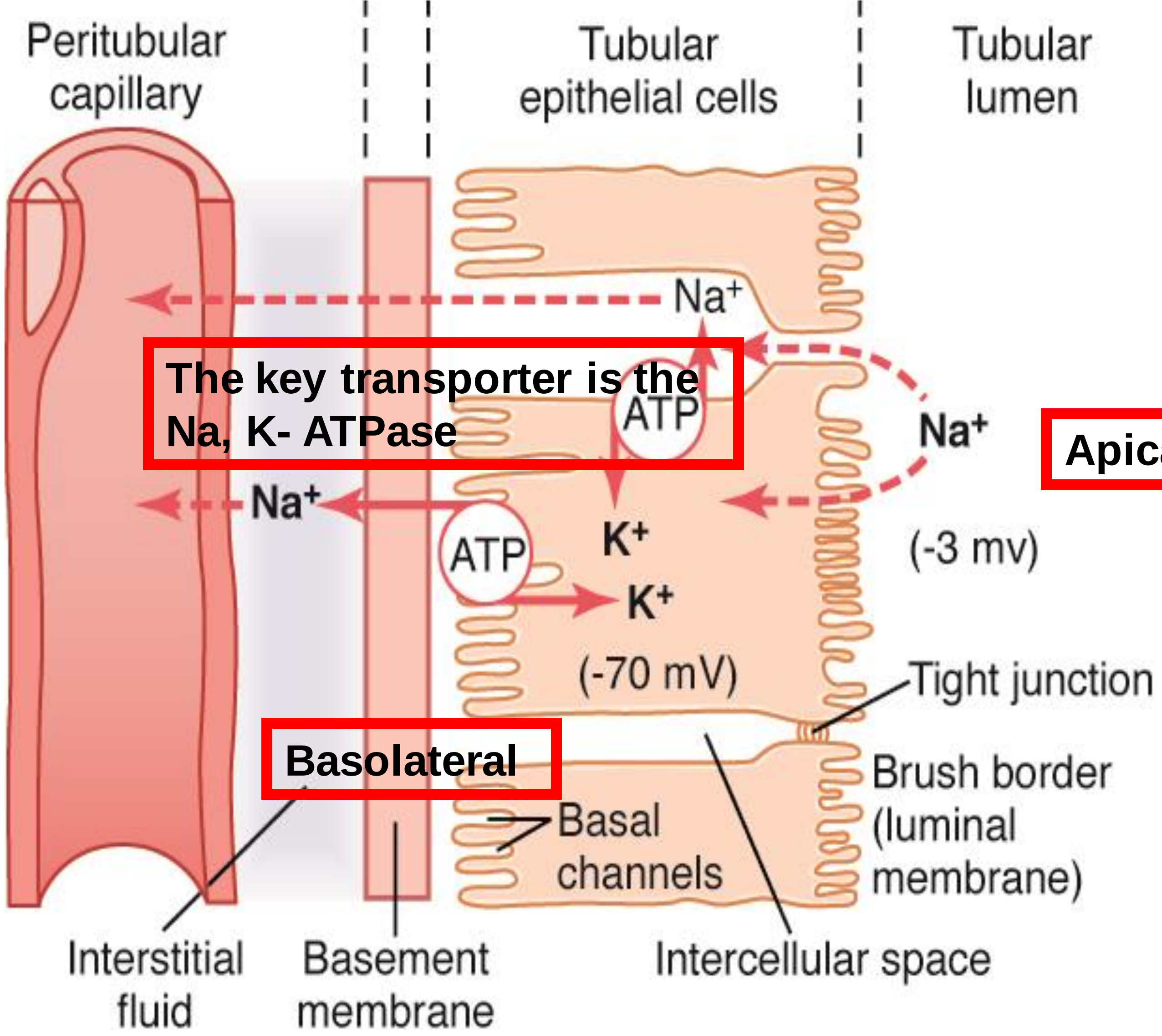
Reabsorption of Water and Solutes



Reabsorption of Water and Solutes



Active Transport

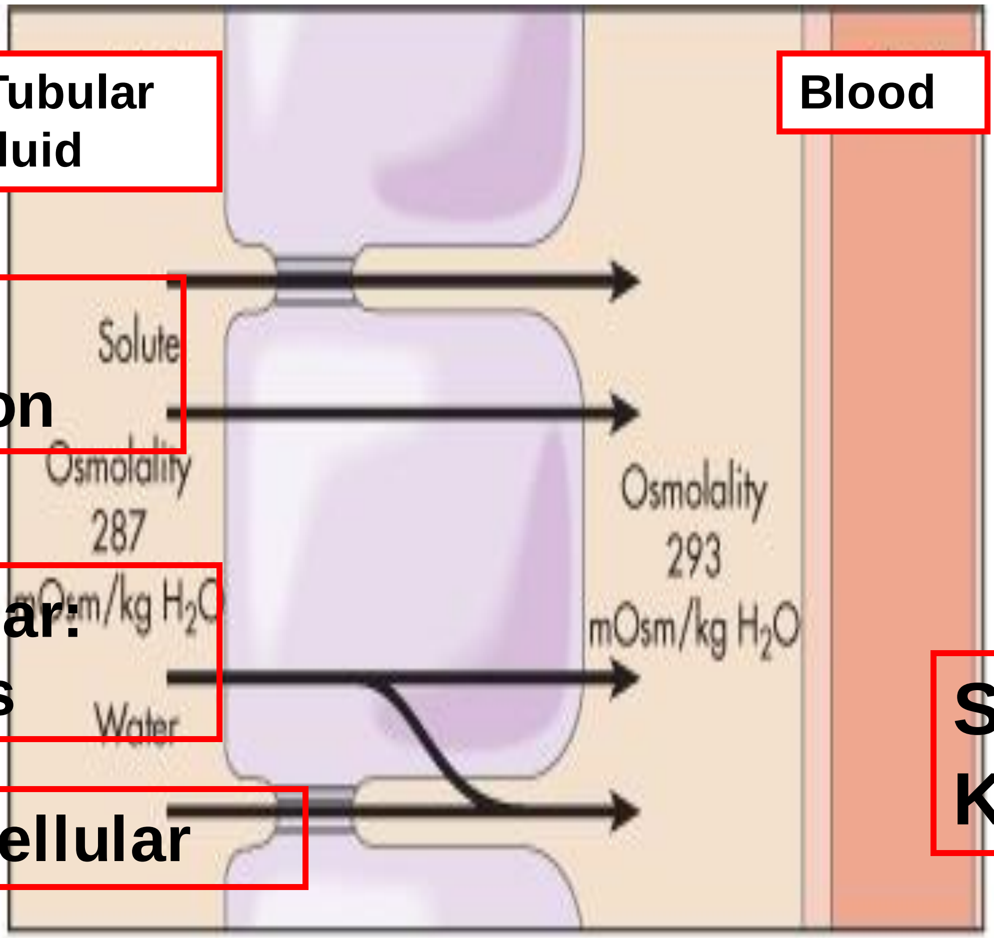


The key transporter is the Na, K- ATPase

Apical

Basolateral

Proximal tubule reabsorption



Tubular fluid

Blood

Water reabsorption

↓

Transcellular: Aquaporins

Paracellular

High osmolality of intercellular spaces drives water reabsorption

Solvent drag of K^+ and Ca^{++}

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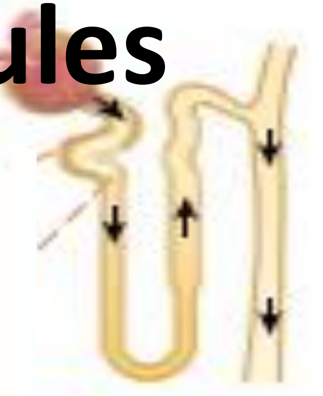
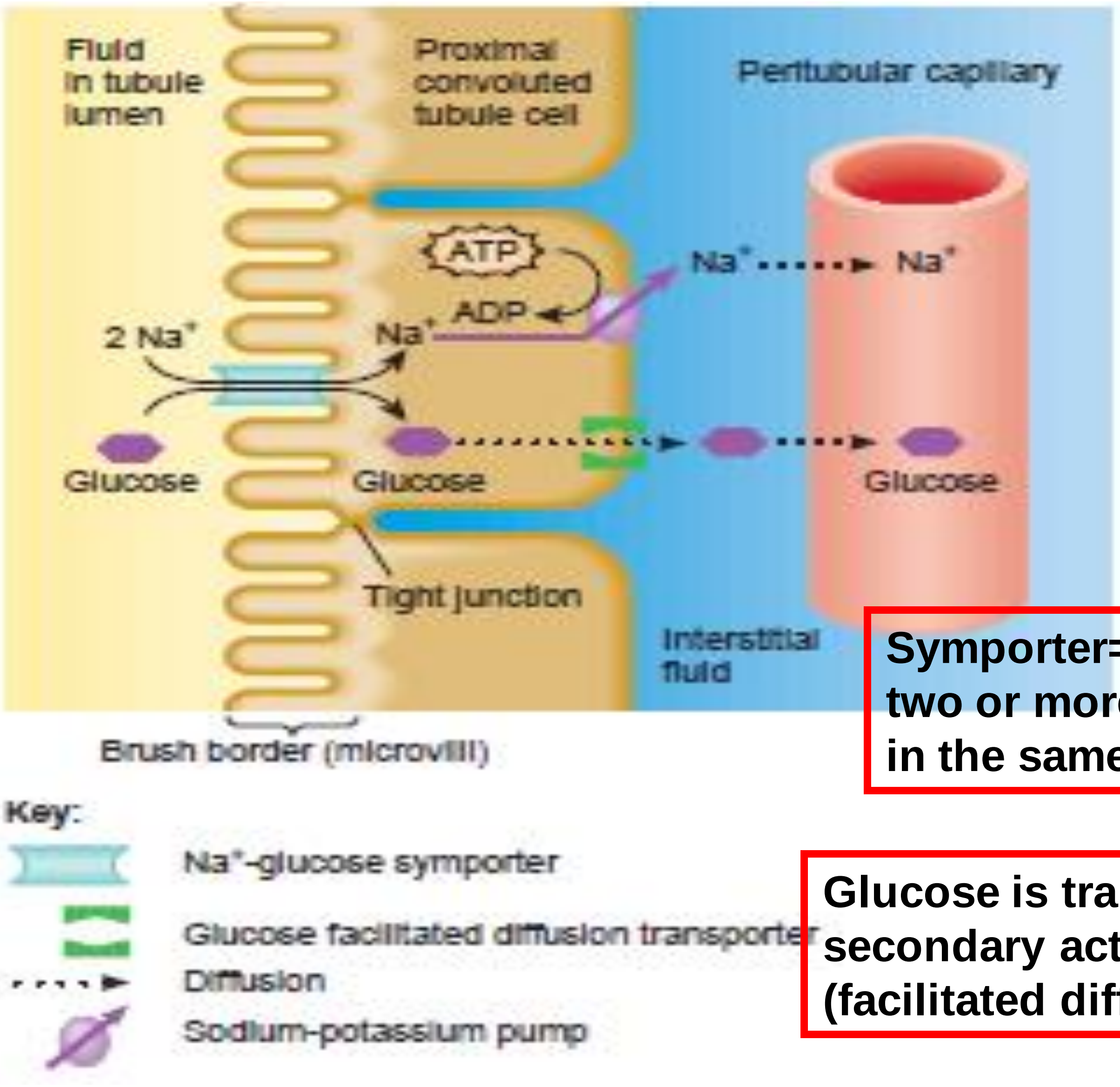
Glucose: Proximal Tubules





Symporter= transports two or more substances in the same direction

Glucose is transported via secondary active transport (facilitated diffusion)

Mechanisms of secondary active transport in Proximal Convoluted Tubules.

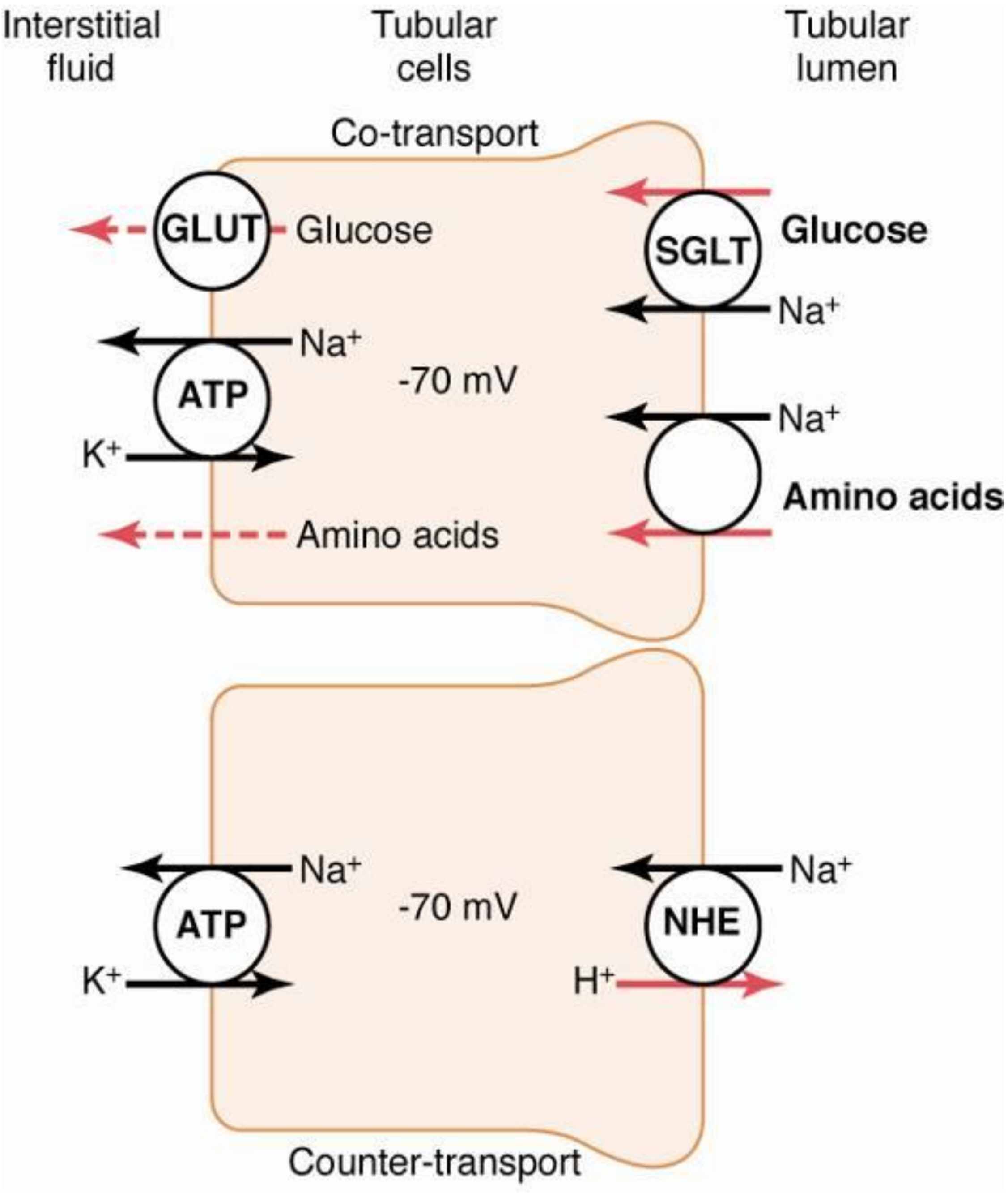


Figure 27-3

Glucose Transport Maximum

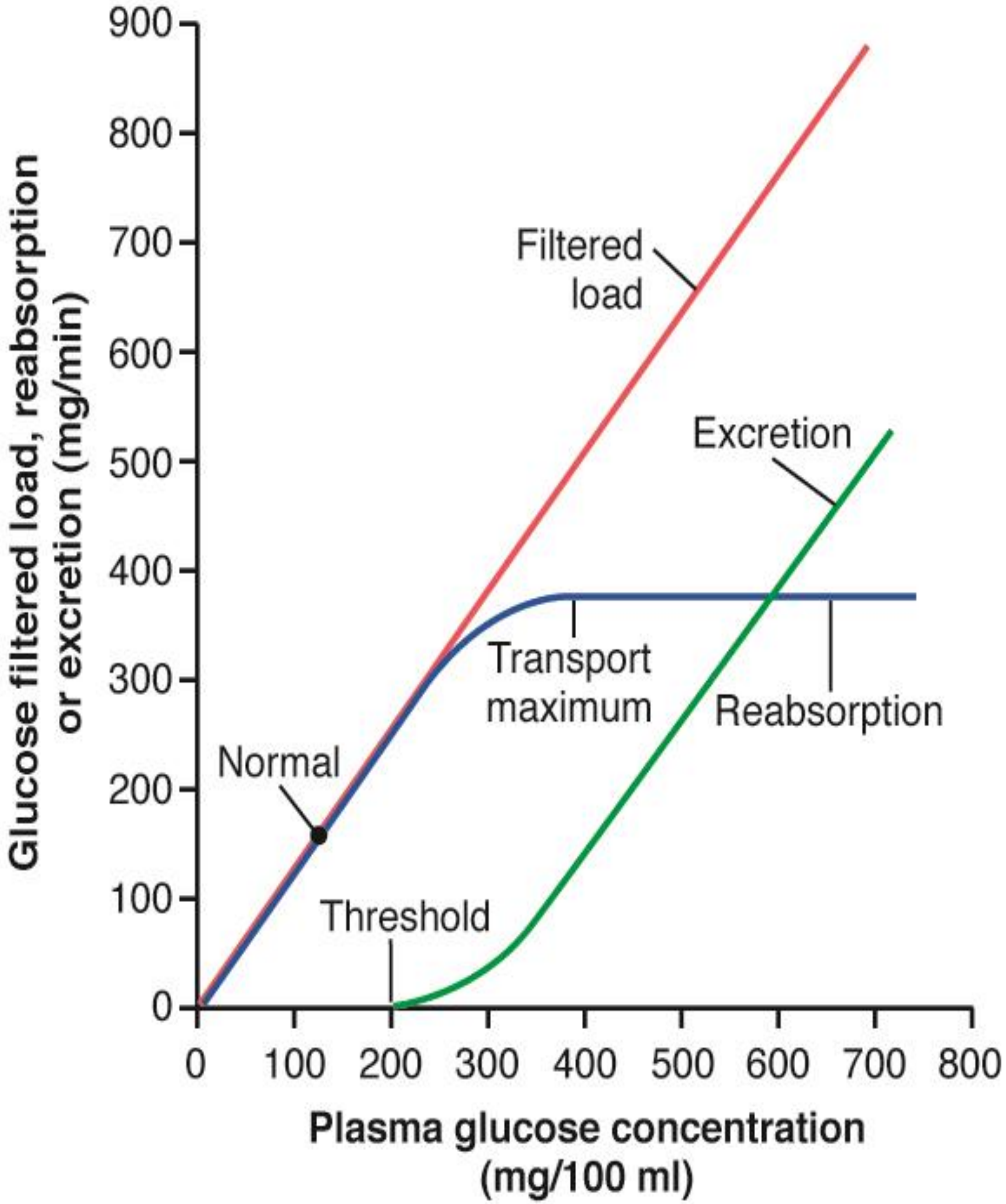
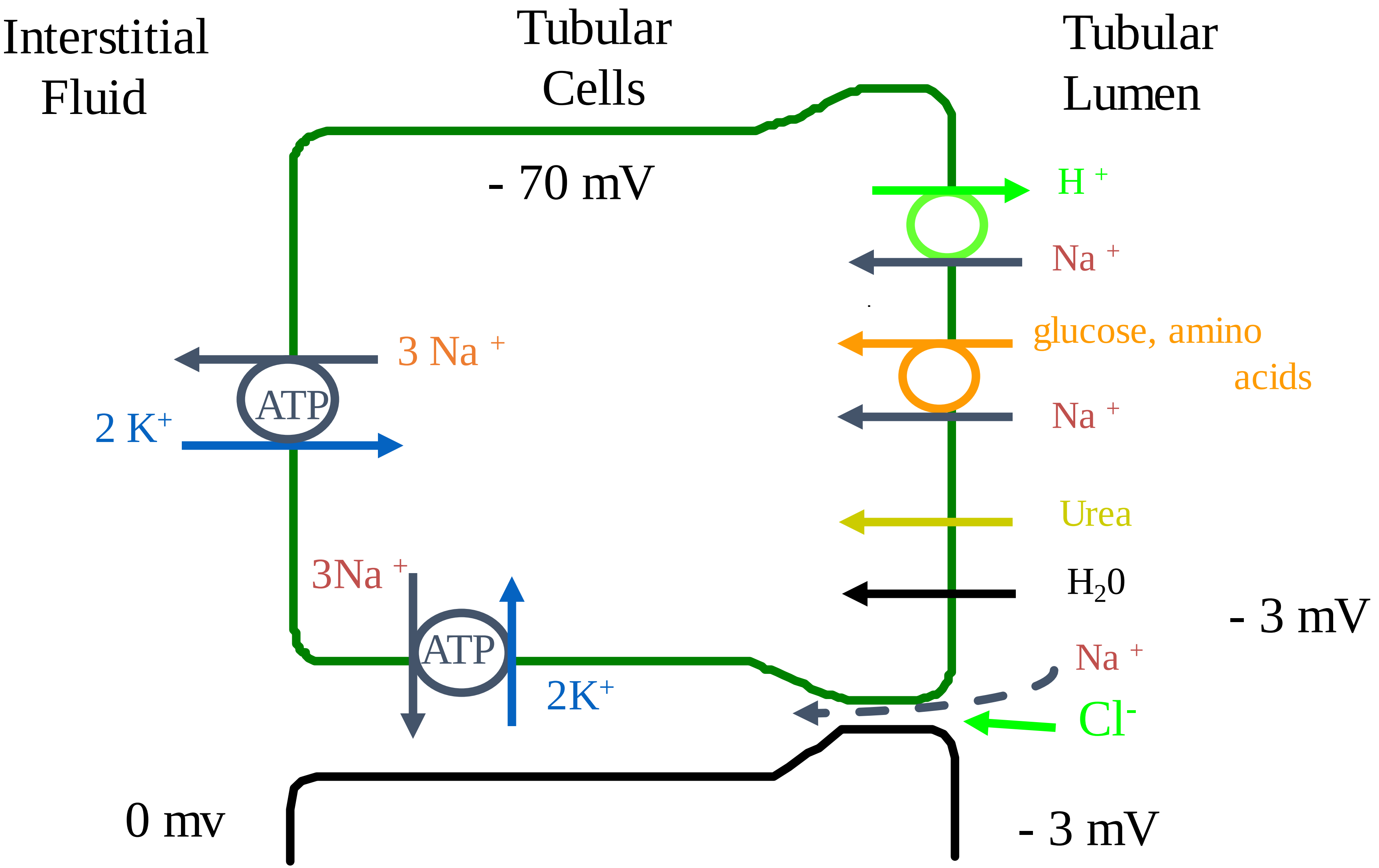
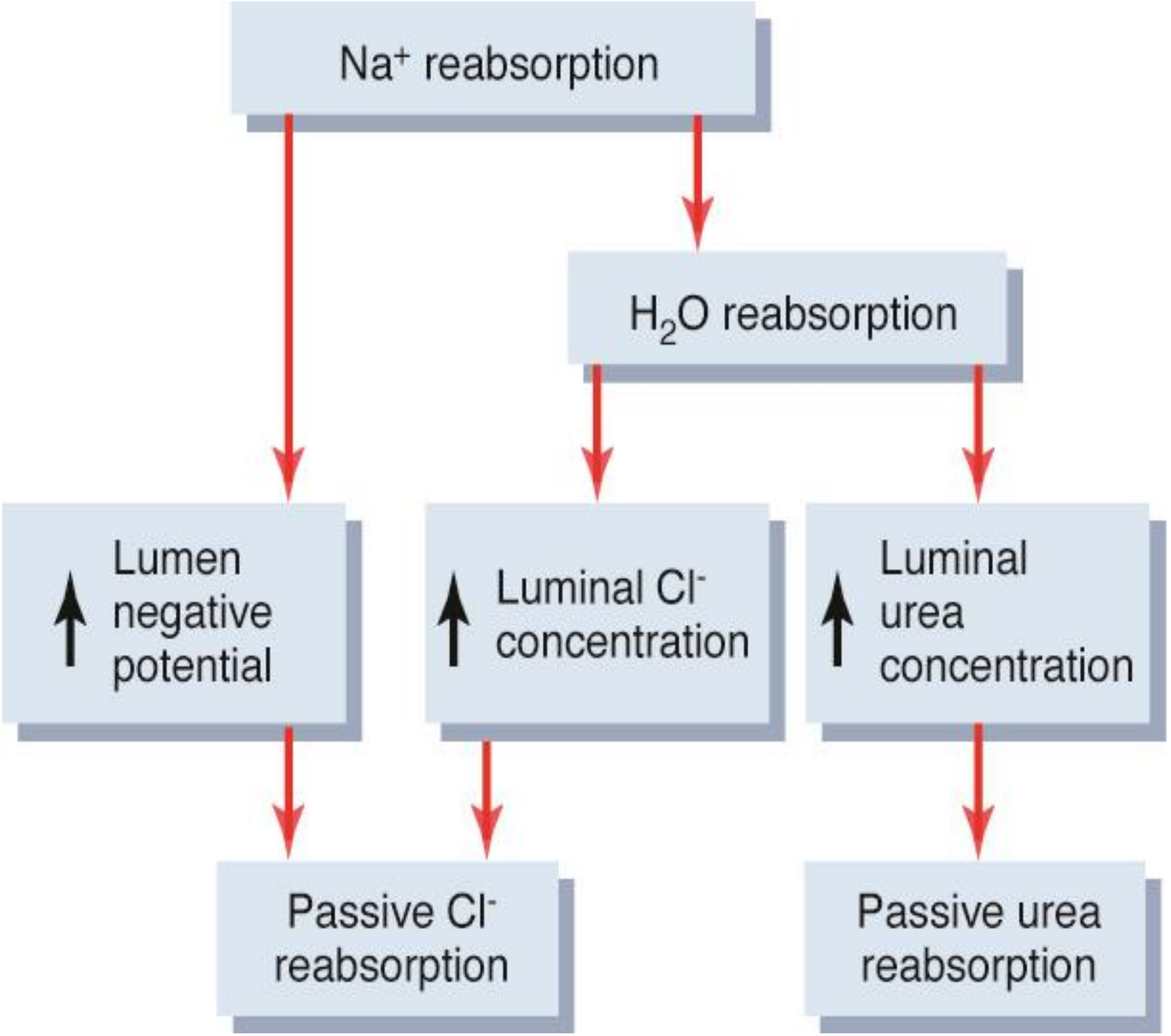


Figure 27-4

Proximal Convoluted Cells



Mechanisms of water, chloride, and urea reabsorption coupled with sodium reabsorption



Na^+ reabsorption

H_2O reabsorption

↑ Lumen negative potential

↑ Luminal Cl^- concentration

↑ Luminal urea concentration

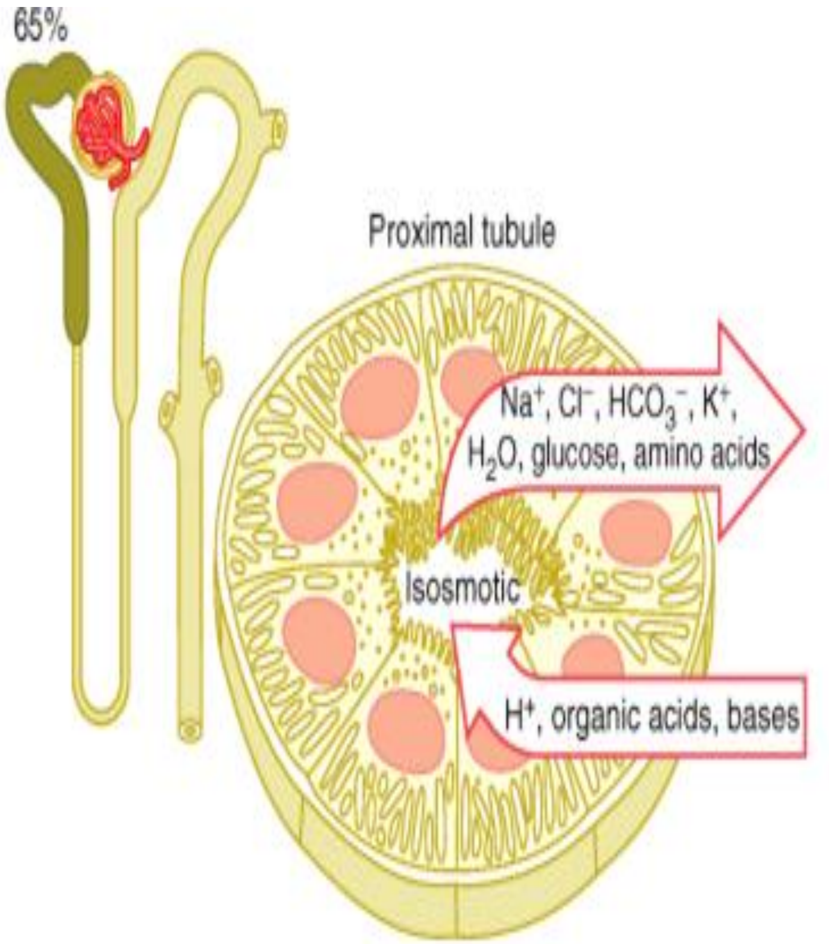
Passive Cl^- reabsorption

Passive urea reabsorption

Figure 27-5

Proximal Tubules

- The proximal tubules reabsorbs about 67% of filtered water, Na^+, Cl^-, K^+, HCO_3^-.
- The proximal tubules reabsorbs almost all glucose and amino acids filtered by the glomeruli.
- The key transporter element is the Na, K- ATP ase in the basolateral membrane.



: Guyton & Hall: Textbook of Medical Physiology 11e - www.studentconsult.

Changes in concentration in proximal tubule

Concentrations of solutes in different parts of the tubule depend on relative reabsorption of the solutes compared to water

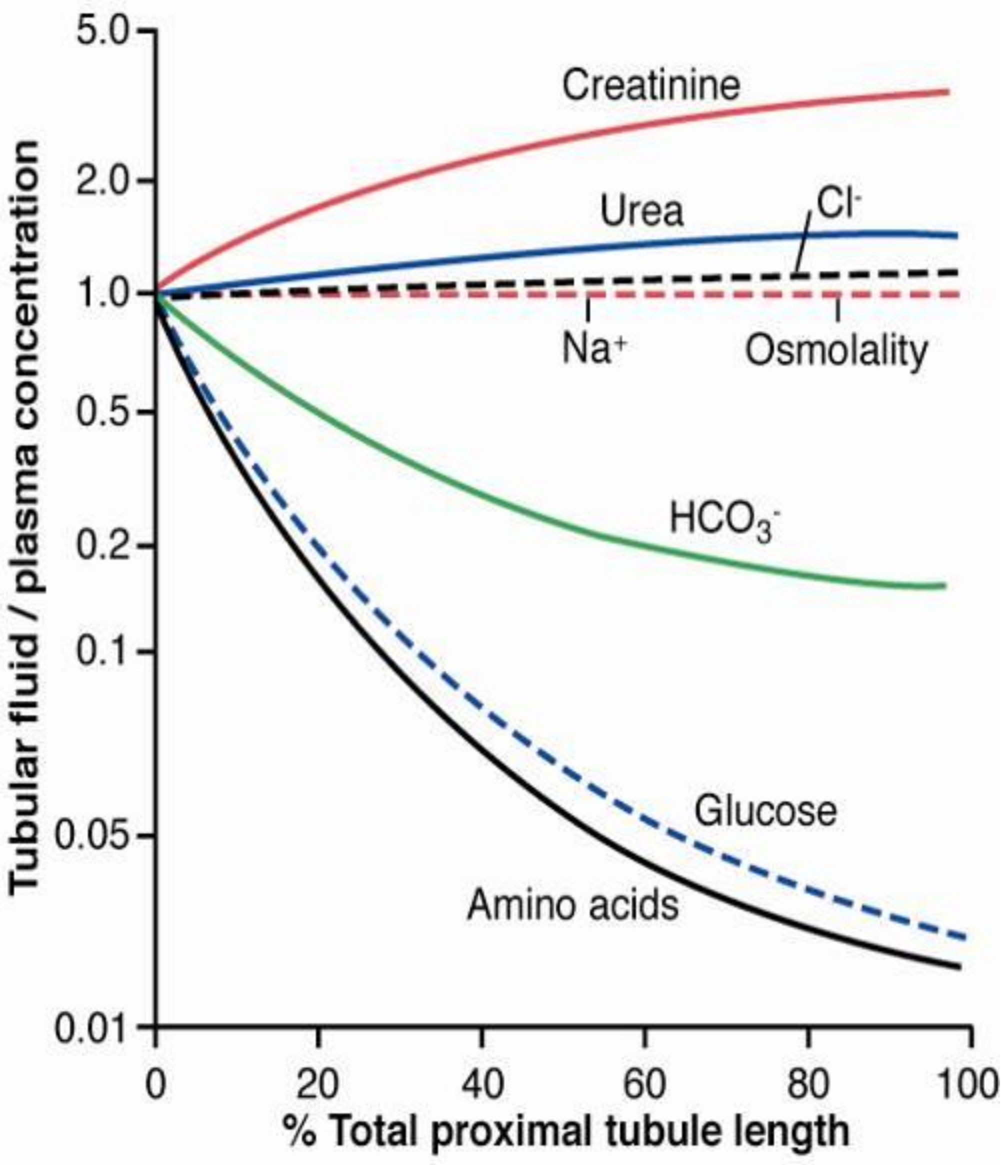
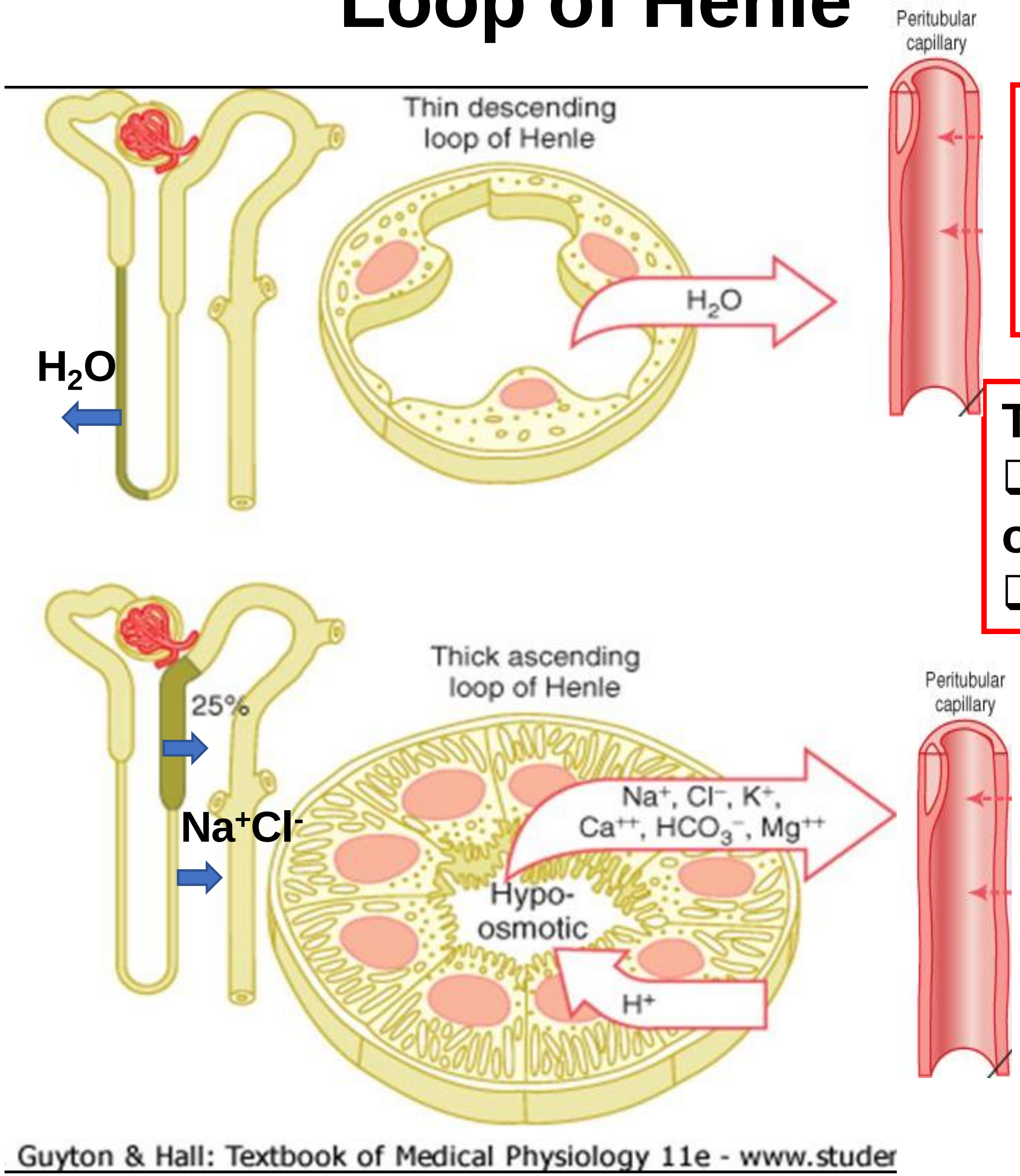


Figure 27-7

Loop of Henle



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Thin Descending
❑15% of H_2O reabsorbed.

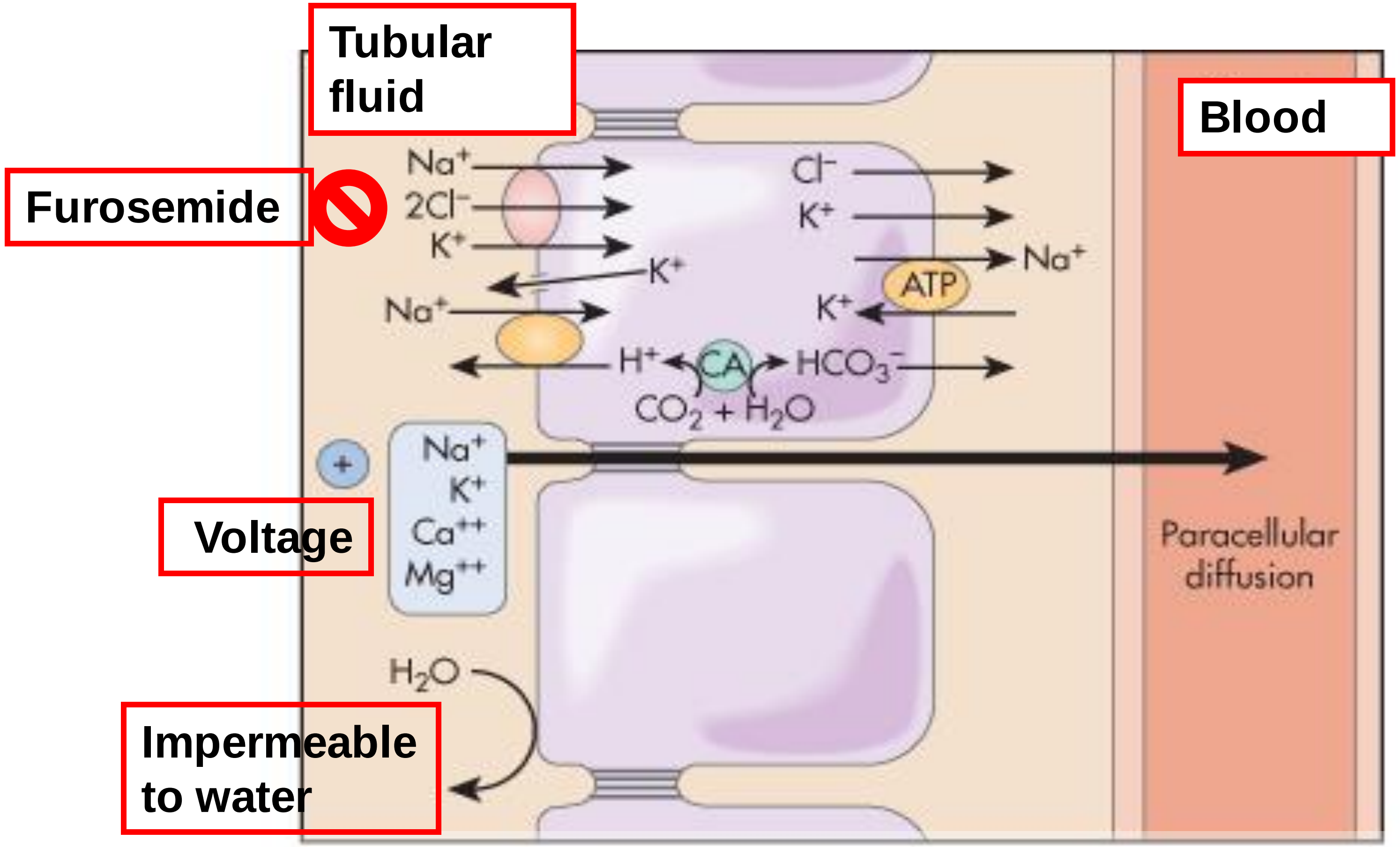
Thin Ascending
❑Passive reabsorption of Na+, K+, Cl-.
❑Impermeable to H_2O.

Thick Ascending
25% of Na+, K+, Cl- HCO_3^-, Ca^{++}, Mg^{++} reabsorbed.
❑Impermeable to H_2O.
❑Called = Diluting segment.
❑Secretion of H^+

Loop of Henle

- Water reabsorption occurs exclusively in the **thin descending** limb of Henle via AQP1 water channels.(**Aquaporins**)
- Reabsorption of **NaCl** occurs in both thin and thick **ascending** limb of Henle.
- In thin ascending limb NaCl is reabsorbed passively. However, in thick ascending limb NaCl is reabsorbed through Na^+-K^+ ATPase in basolateral membrane ans .
- Ascending limb is impermeable to water.
- Reabsorption of Ca^{++} and $HCO3^-$ occurs also in Loop of Henle.

Thick ascending limb of Henle



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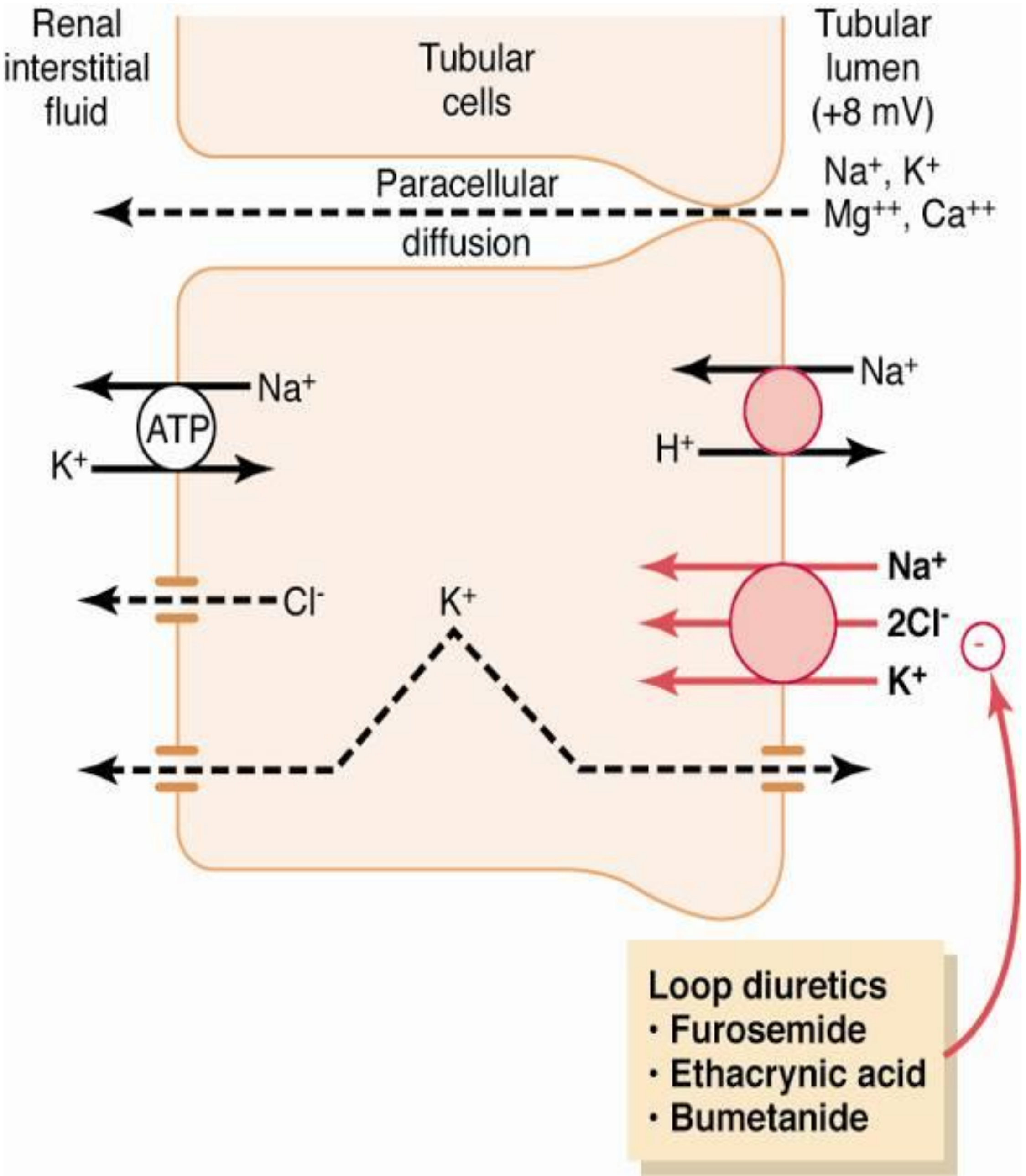
of NaCl Reabsorption:
❑50% is Transcellular
❑50% is Paracellular

Sodium chloride and potassium transport in thick ascending loop of Henle



Loop diuretics

- **Furosemide**
- **Ethacrynic acid**
- **Bumetanide**

Figure 27-9

Early Distal Tubule

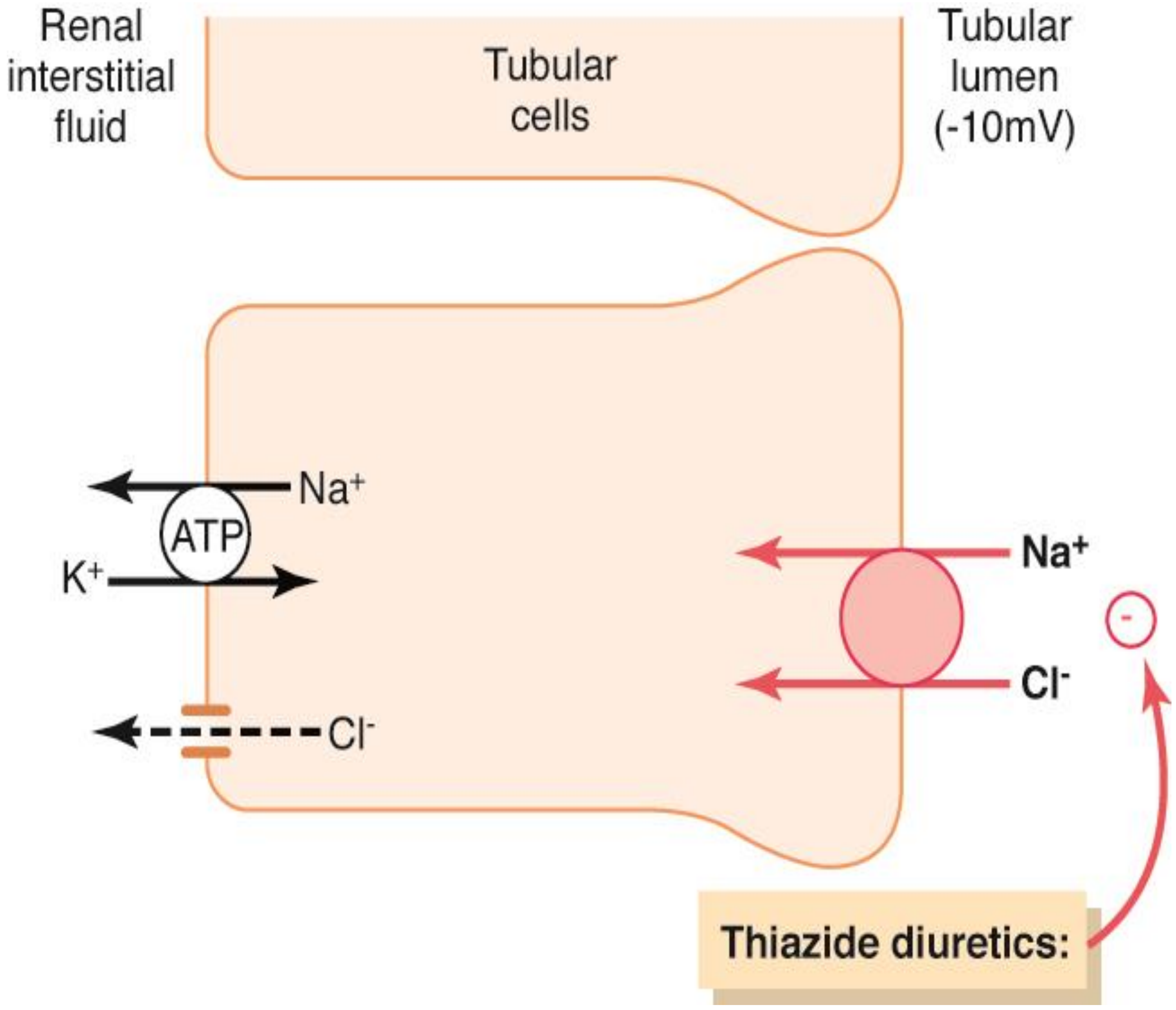


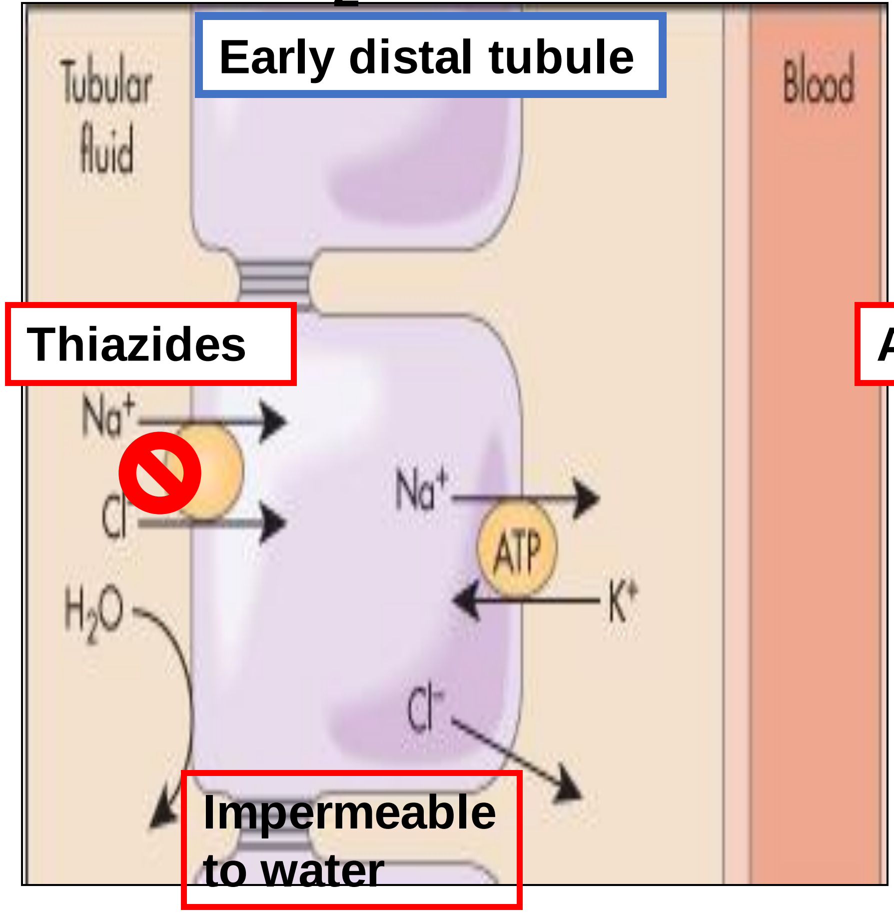
Figure 27-10

Early Distal Tubule

- Functionally similar to thick ascending loop
- Not permeable to water (called diluting segment)
- Active reabsorption of Na^+, Cl^-, K^+, Mg^{++}
- Contains macula densa

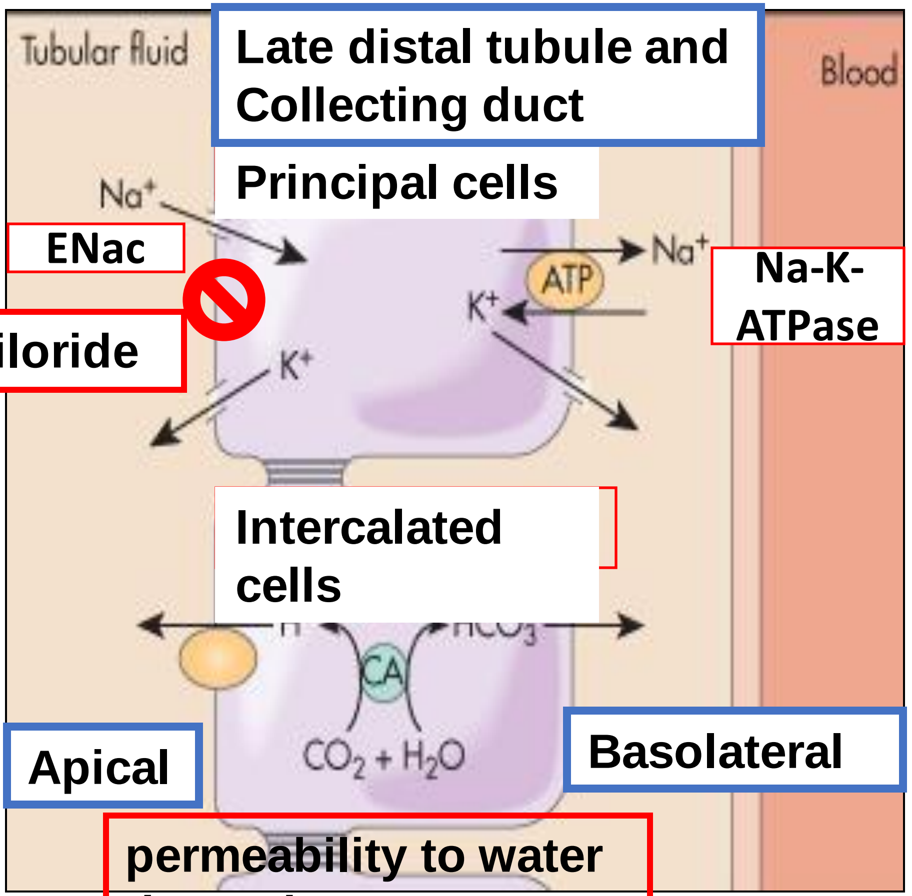
Distal tubule and collecting duct

- ❑ **Reabsorbs 7% NaCl, secrets K+ and H+ and reabsorbs**
  8-17% H_2O


Early distal tubule

Thiazides

Impermeable to water


Late distal tubule and Collecting duct

Principal cells

ENac

Amiloride

Na-K-ATPase

Intercalated cells

Apical

Basolateral

permeability to water depends on ADH

Early and Late Distal Tubules and Collecting Tubules.

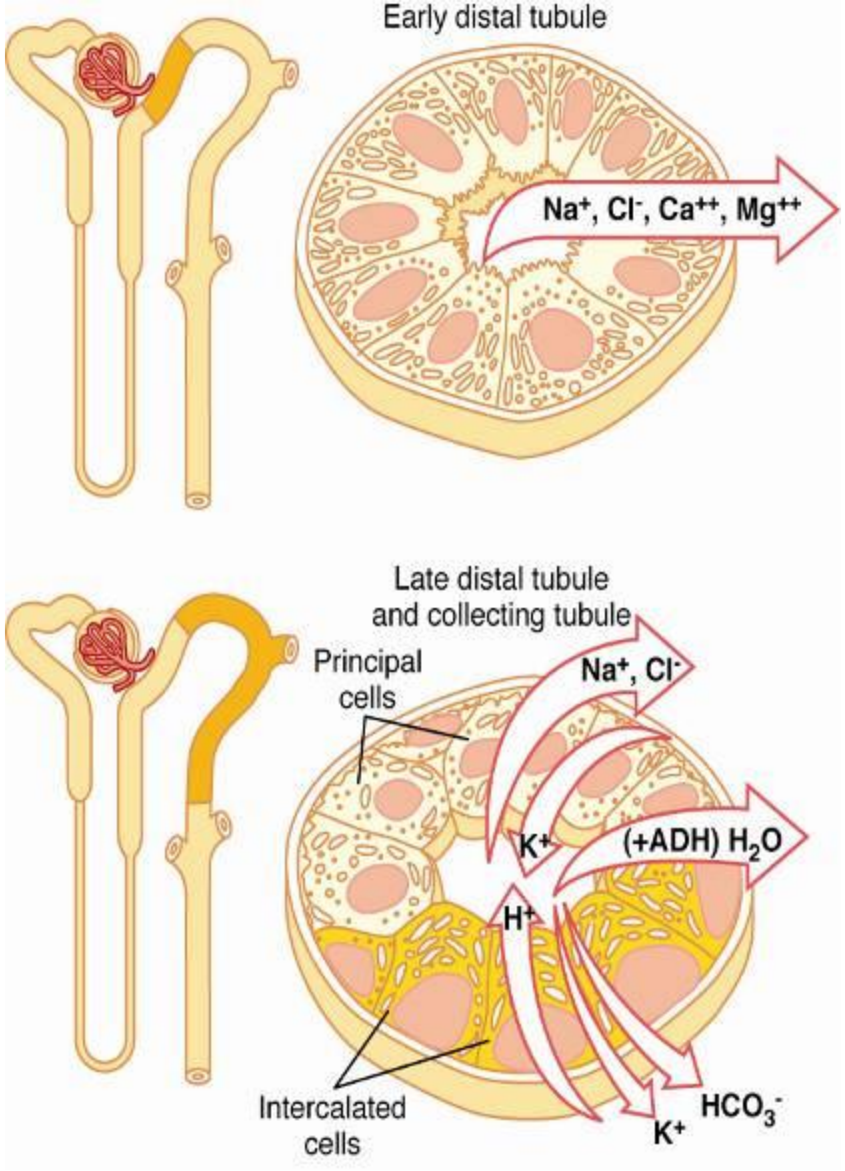


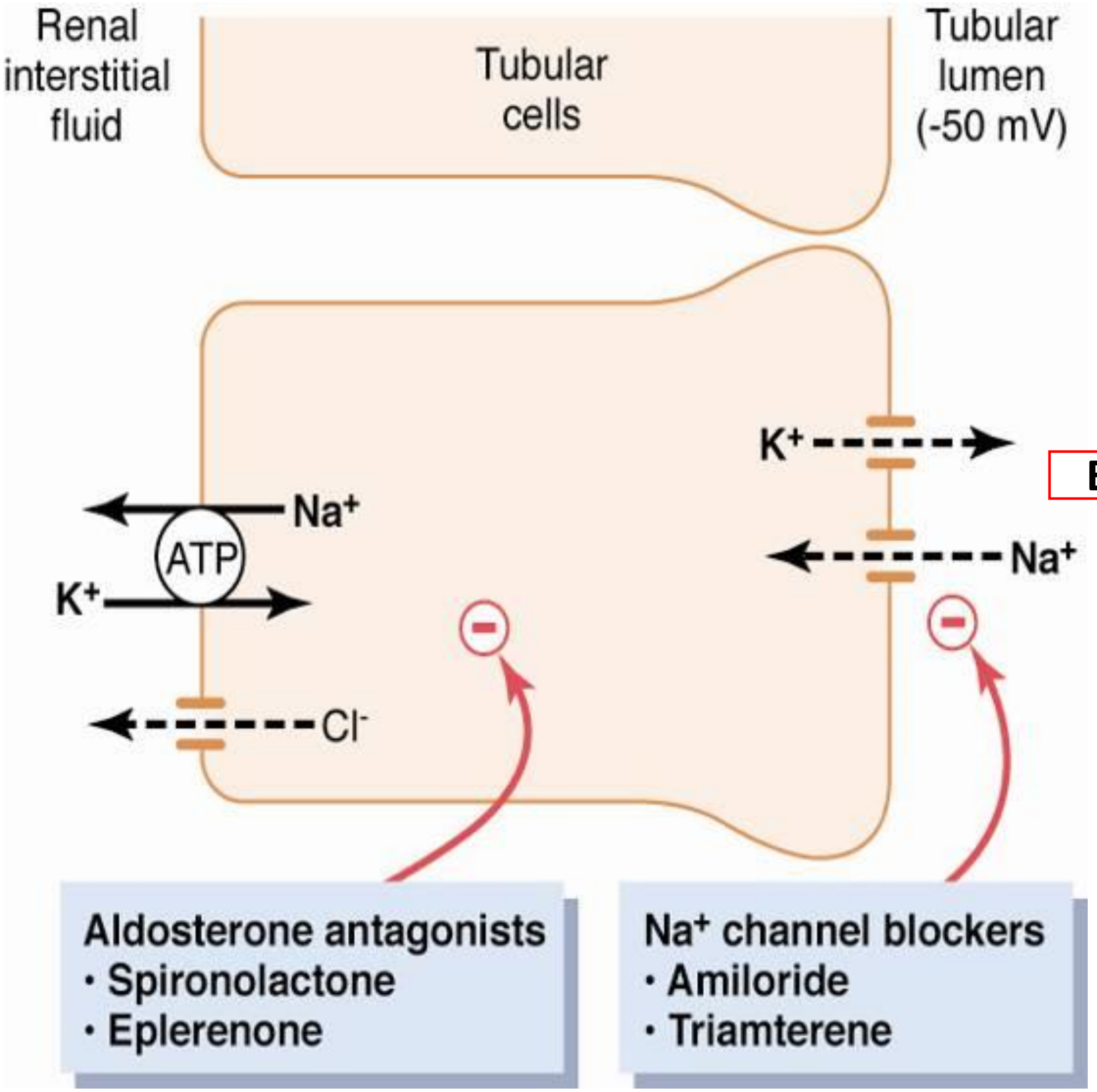
Figure 27-11

~ 5% of filtered load
NaCl reabsorbed

- not permeable to H_2O
- not very permeable to urea

- permeablility to H_2O depends on ADH
- not very permeable to urea

Late Distal and Cortical Collecting Tubules **Principal Cells** – Secrete K^+

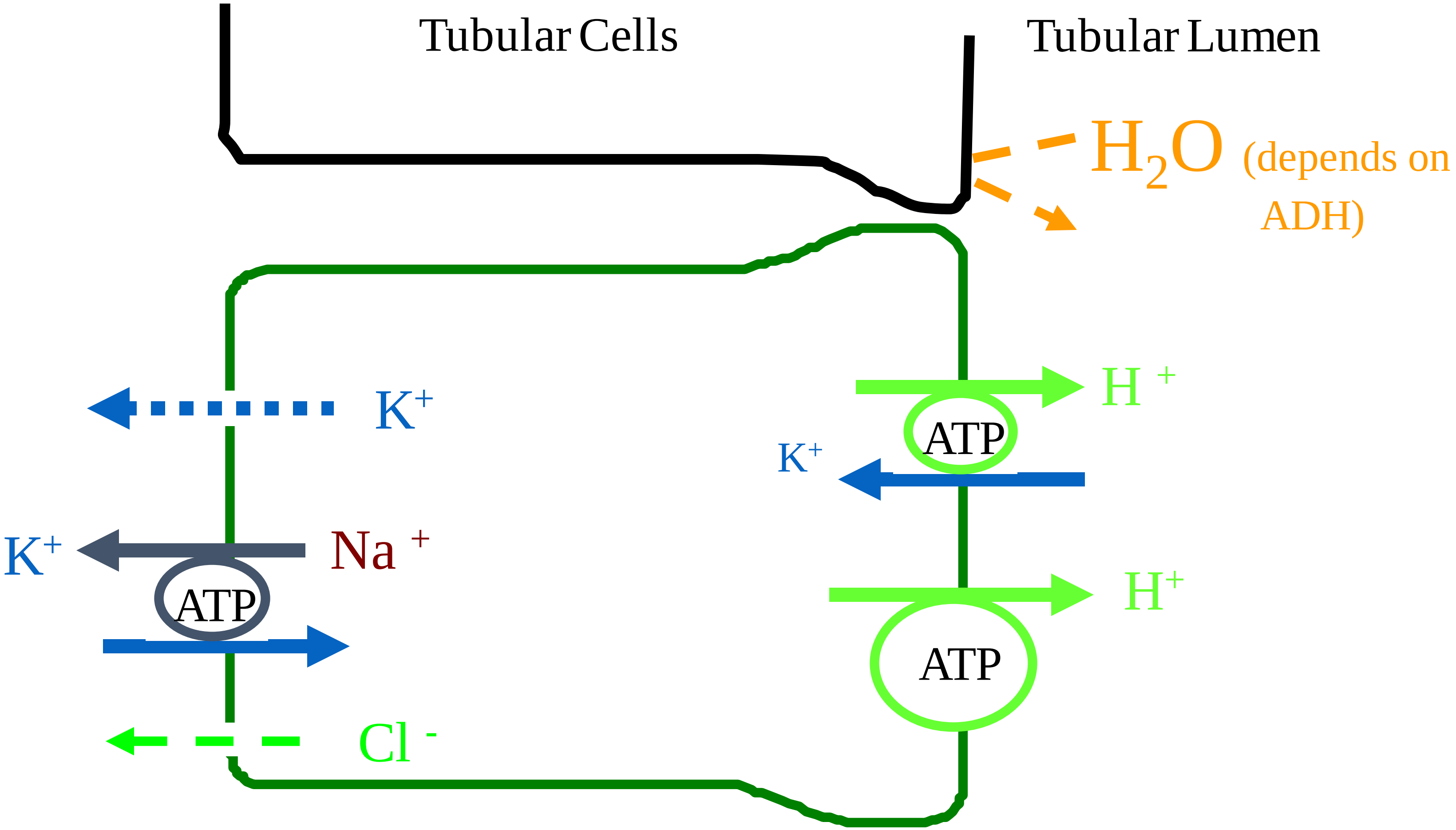


Aldosterone antagonists
- Spironolactone
- Eplerenone

Na^+ channel blockers
- Amiloride
- Triamterene

Figure 27-12

Late Distal and Cortical Collecting Tubules **Intercalated Cells** –Secrete H^+



Transport characteristics of medullary collecting ducts

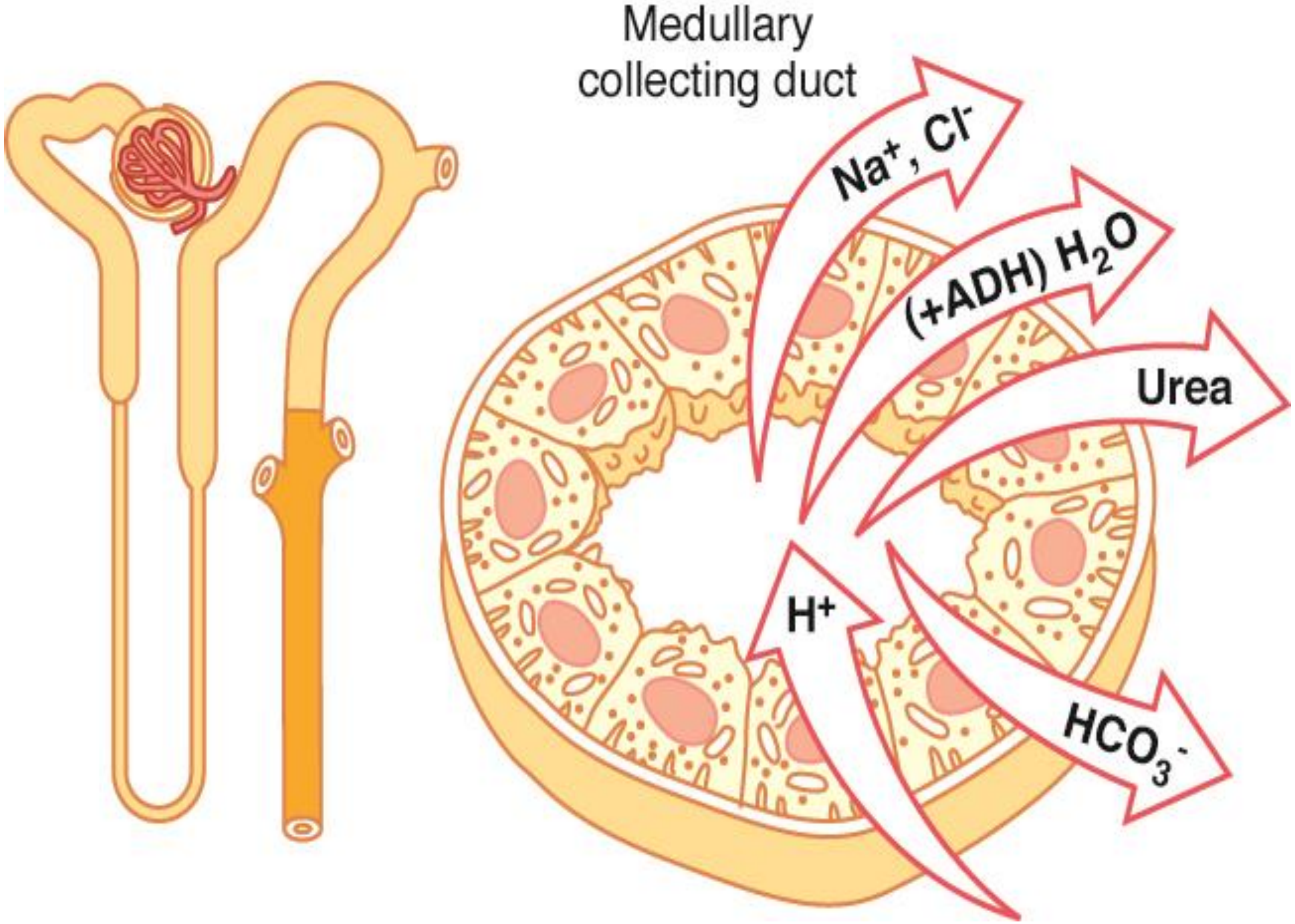
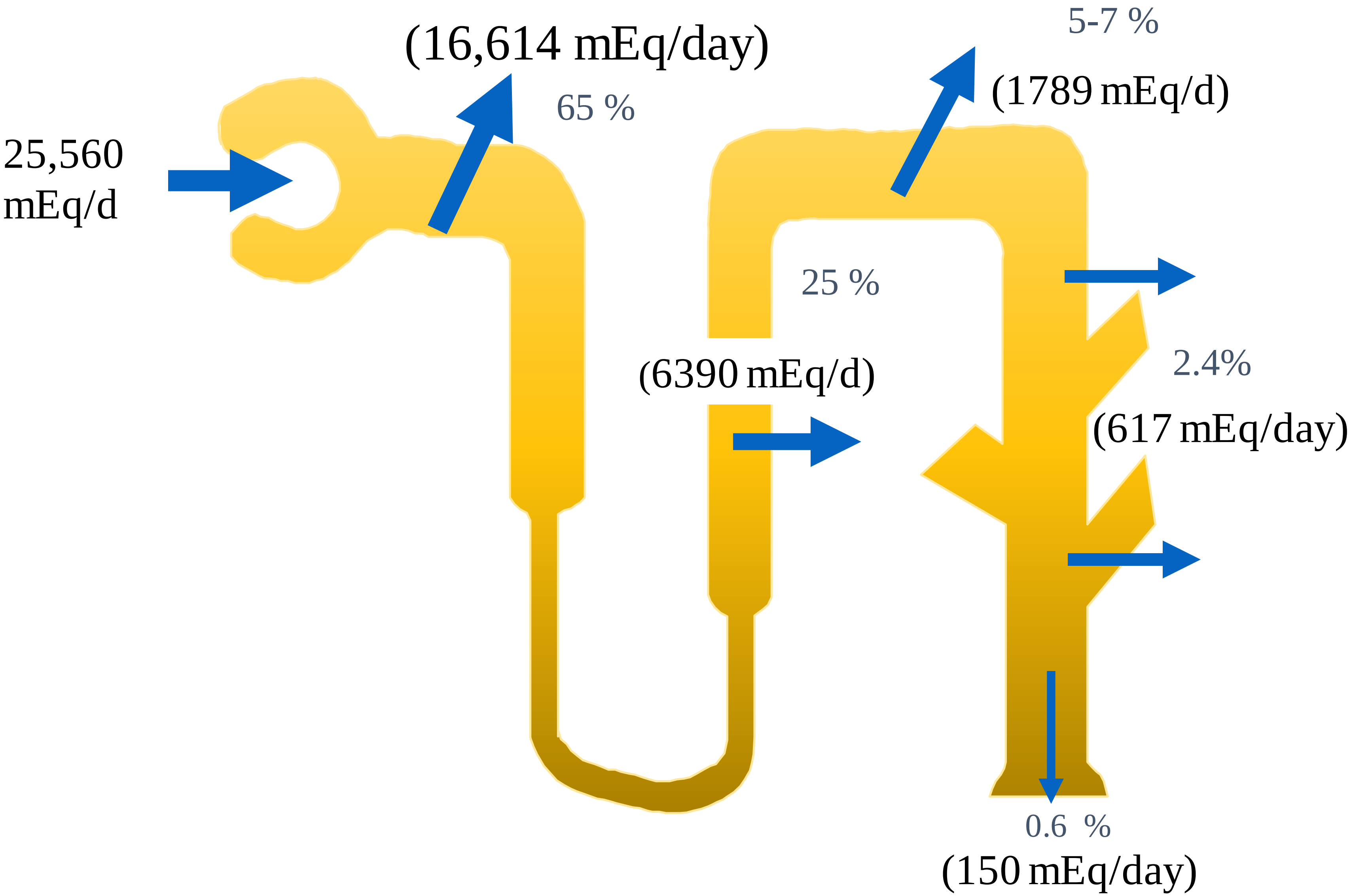


Figure 27-13

Normal Renal Tubular Na$^+$ Reabsorption



Concentrations of solutes in different parts of the tubule depend on relative reabsorption of the solutes compared to water

- If water is reabsorbed to a greater extent than the solute, the solute will become more concentrated in the tubule (e.g. creatinine, inulin)

- If water is reabsorbed to a lesser extent than the solute, the solute will become less concentrated in the tubule (e.g. glucose, amino acids)

Changes in concentrations of substances in the renal tubules

Concentrations of solutes in different parts of the tubule depend on relative reabsorption of the solutes compared to water

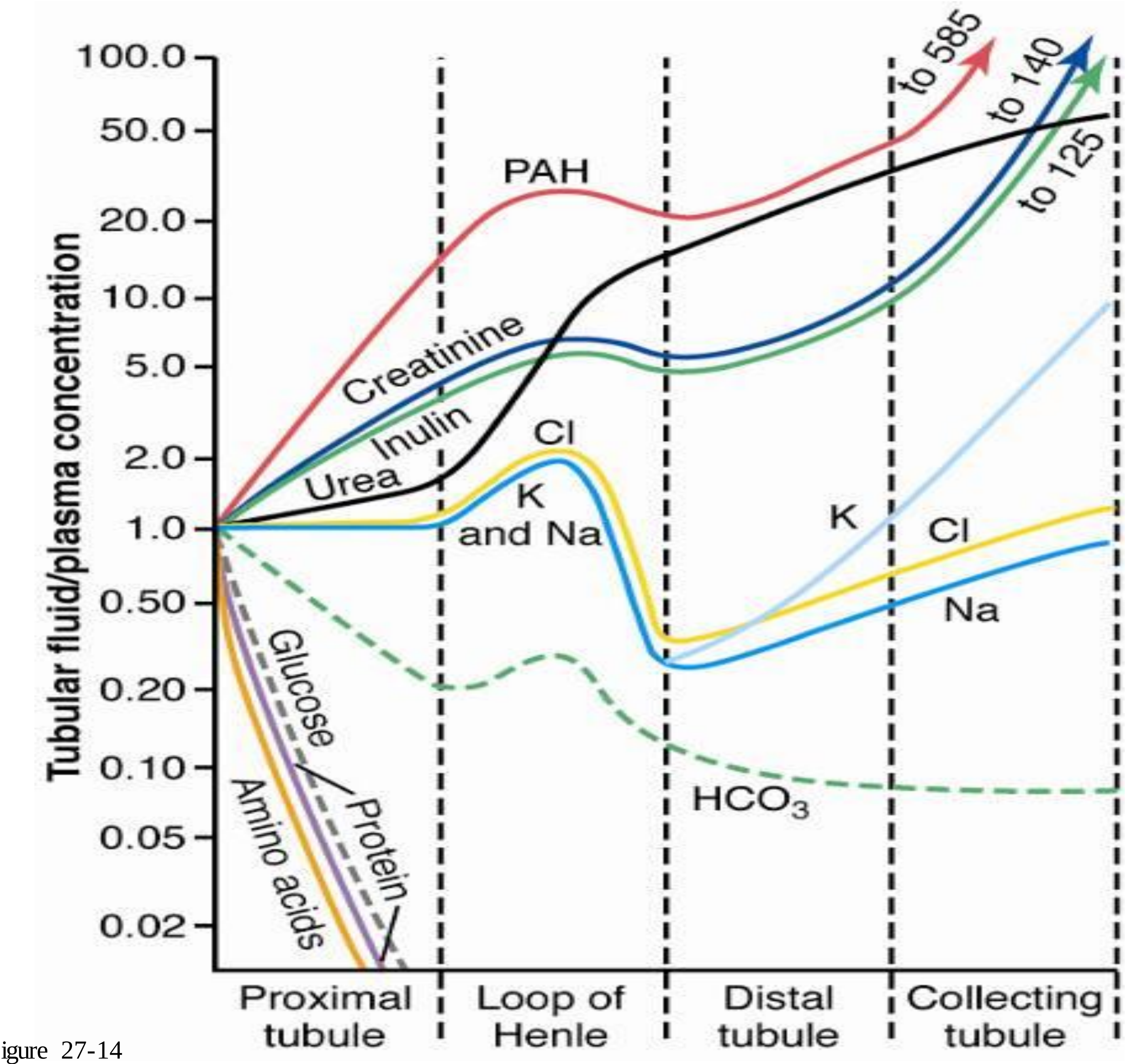


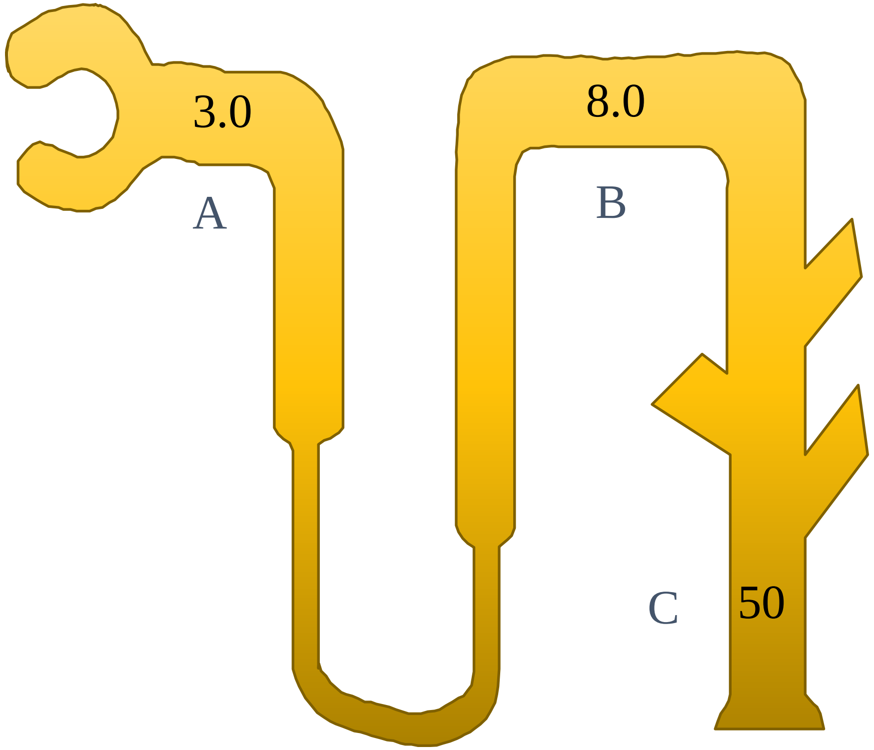
Figure 27-14

The figure below shows the concentrations of inulin at different points along the tubule, expressed as the tubular fluid/plasma (TF/P_{inulin}) concentration of inulin. If inulin is not reabsorbed by the tubule, what is the percentage of the filtered water that has been reabsorbed or remains at each point ? What percentage of the filtered water has been reabsorbed up to that point?

A = 1/3 (33.33 %) remains
66.67 % reabsorbed

B = 1/8 (12.5 %) remains
87.5 % reabsorbed

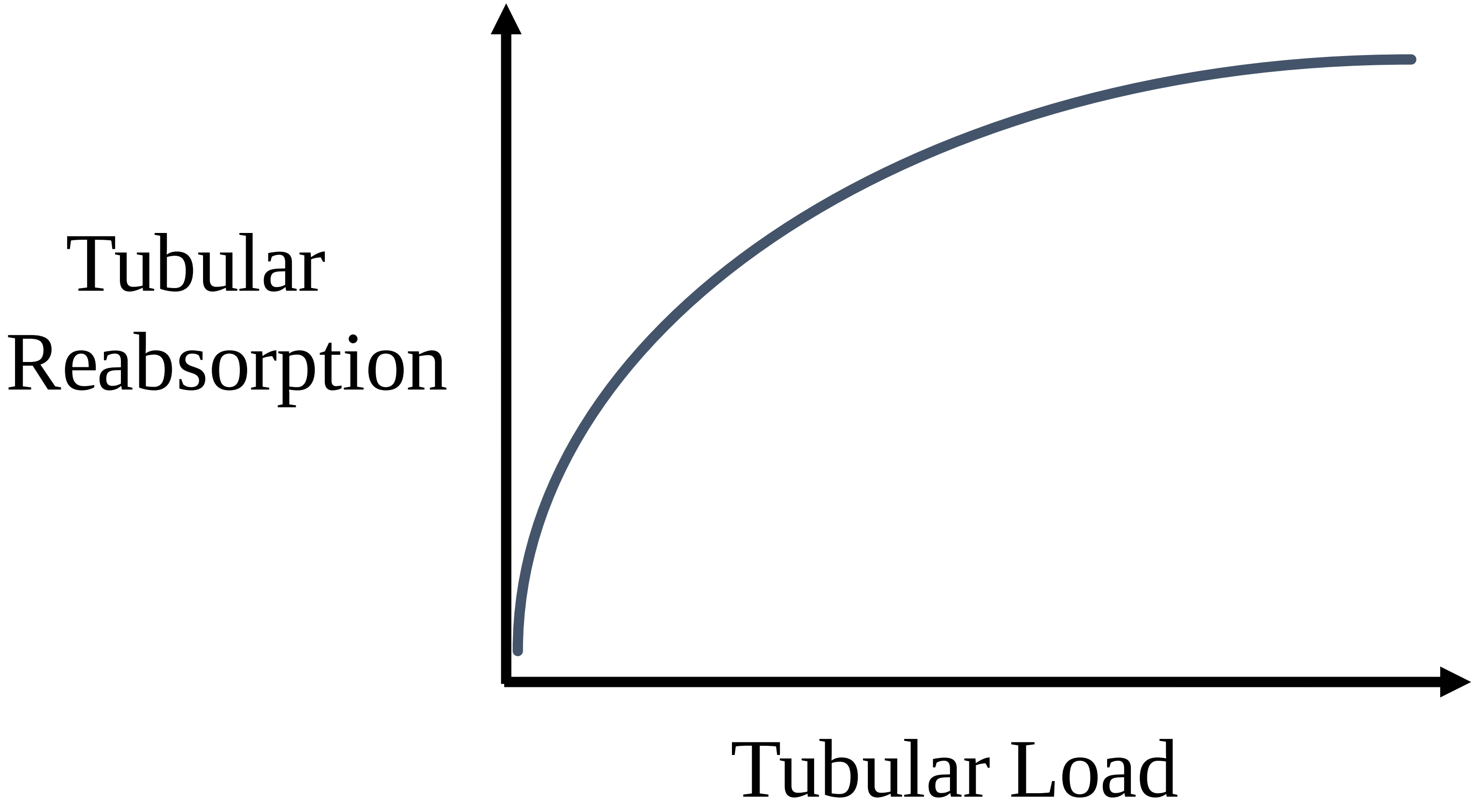
C = 1/50 (2.0 %) remains
98.0 % reabsorbed



Regulation of Tubular Reabsorption

- Glomerulotubular Balance
- Peritubular Physical Forces
- Hormones
    - aldosterone
    - angiotensin II
    - antidiuretic hormone (ADH)
    - natriuretic hormones (ANF)
    - parathyroid hormone
- Sympathetic Nervous System
- Arterial Pressure (pressure natriuresis)
- Osmotic factors

Glomerulotubular Balance



Importance of Glomerulotubular Balance in Minimizing Changes in Urine Volume

GFR	Reabsorption	% Reabsorption	Urine Volume
	no glomerulotubular balance		
125	124	99.2	1.0
150	124	82.7	26.0
	“perfect” glomerulotubular balance		
150	148.8	99.2	1.2

Peritubular capillary reabsorption

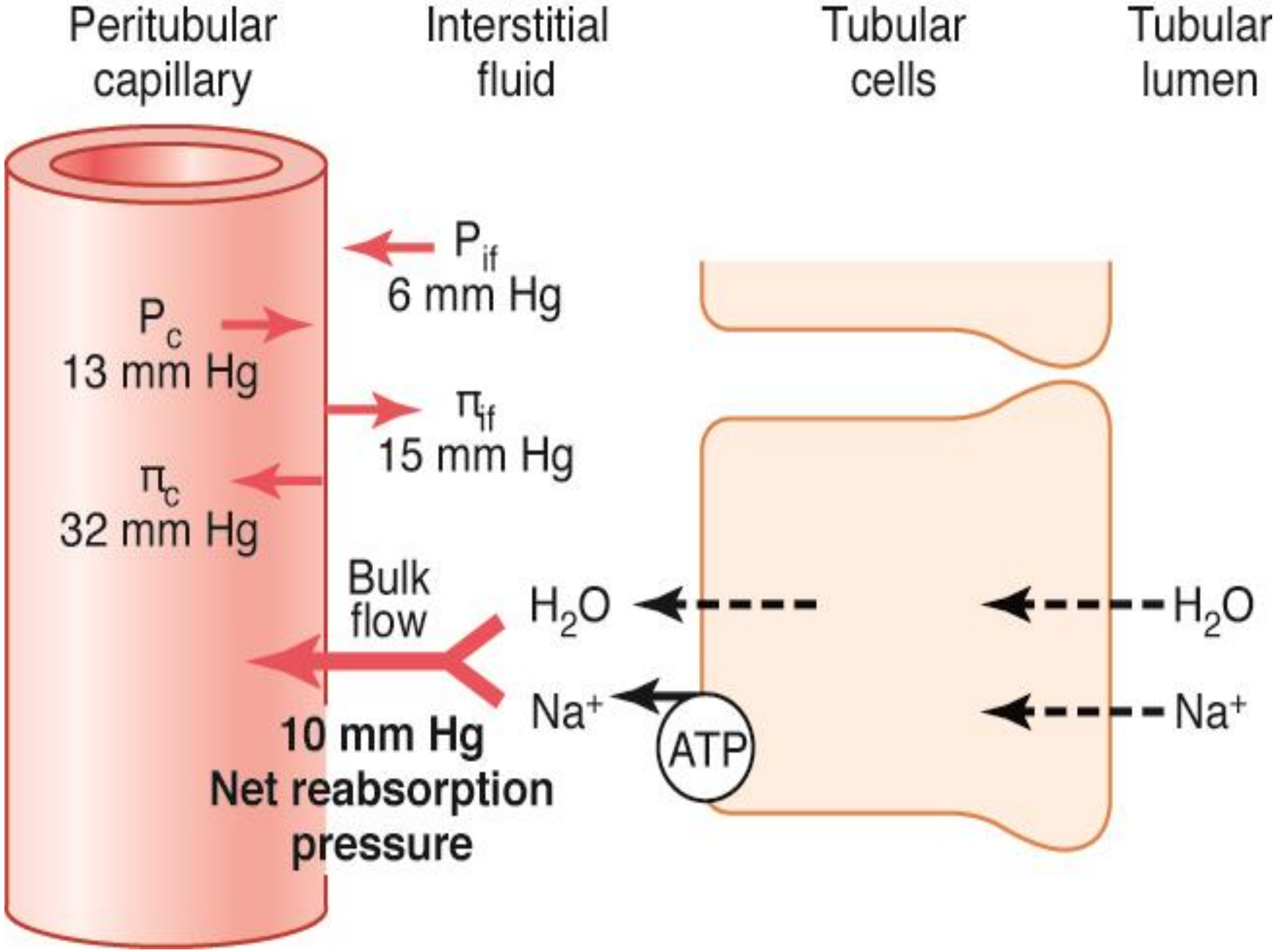
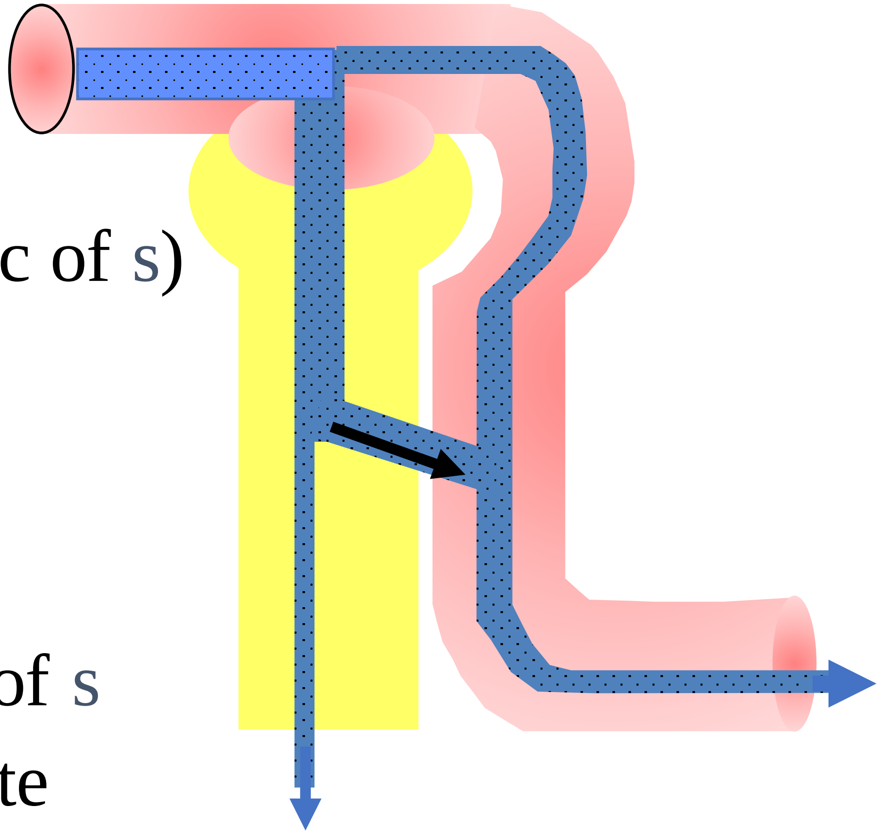


Figure 27-15

Calculation of Tubular Reabsorption

(when Excret s < Filt s)

Reabsorption = Filtration -Excretion



Filt s = GFR x Ps

(Ps = Plasma conc of s)

Excret s = Us x V

Us = Urine conc of s

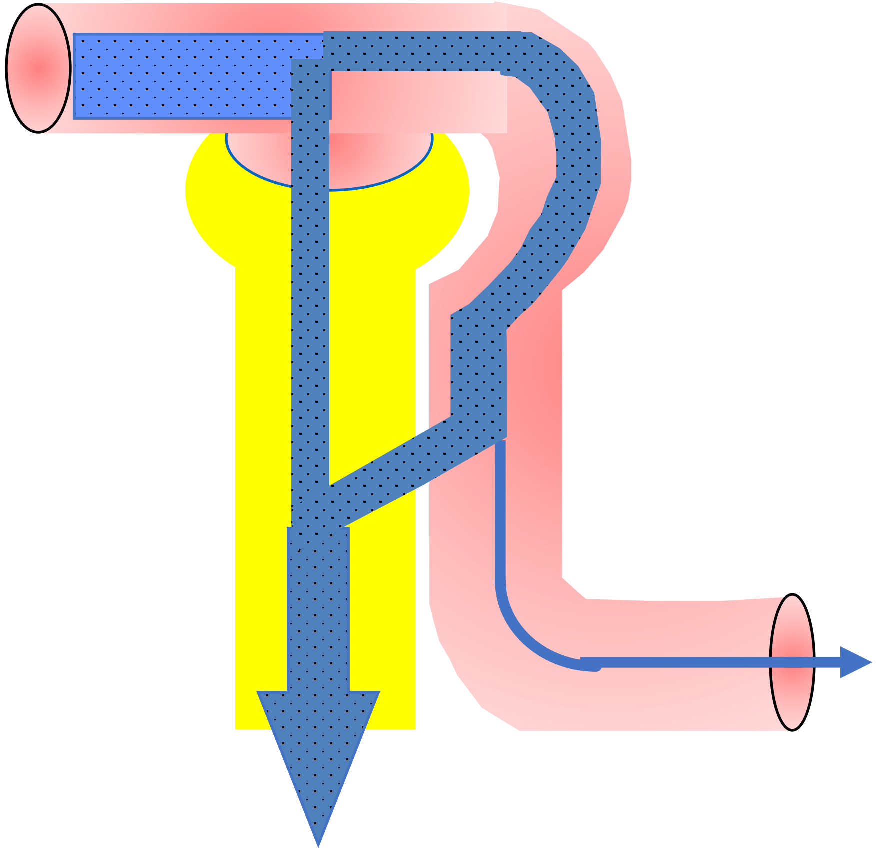
V = urine flow rate

Calculation of Tubular Secretion

(when Excret s > Filt s)

Secretion = Excretion - Filtration

Filt s = GFR x Ps



Excret s = Us x V

Example: Given the following data, calculate the rate of Na^+ filtration, excretion, reabsorption, and secretion

GFR =100 ml/min (0.1 L/min)
P_{Na} = 140 mEq/L
urine flow = 1 ml/min (.001 L/min)
urine Na conc = 100 mEq/L

Filtration Na = GFR x P_{Na}

= 0.1 L/min x 140 mEq/L = 14 mEq/min

Excretion Na = Urine flow rate x Urine Na conc

=.001 L/min x 100 mEq/L
= 0.1 mEq/min

Example: Given the following data, calculate the rate of Na^+ filtration, excretion, reabsorption, and secretion

GFR =100 ml/min;
P_{Na} = 140 mEq/L
urine flow = 1 ml/min;
urine Na conc = 100 mEq/L

Filtration Na = 0.1 L/min x 140 mEq/L = 14 mEq/min
Excretion Na = .001 L/min x 100 mEq/L = 0.1 mEq/min
Reabsorption Na = Filtration Na - Excretion Na

Reabs Na = 14.0 - 0.1 = 13.9 mEq/min

Secretion Na = There is no net secretion of Na since
Excret Na < Filt Na

Transport Maximum

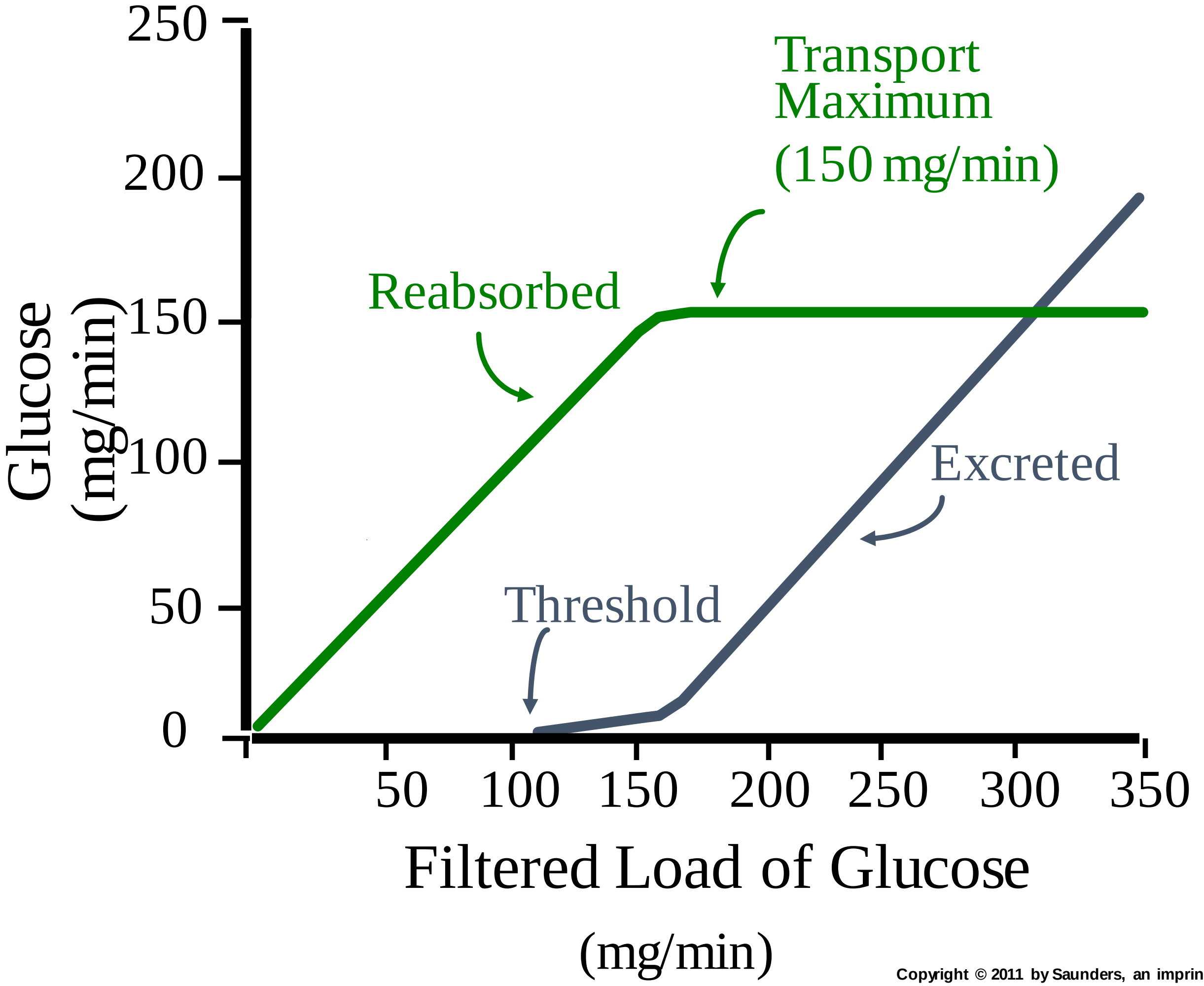
Some substances have a maximum rate of tubular transport due to saturation of carriers, limited ATP, etc

- Transport Maximum: Once the transport maximum is reached for all nephrons, further increases in tubular load are not reabsorbed and are excreted.
- Threshold is the tubular load at which transport maximum is exceeded in some nephrons. This is not exactly the same as the transport maximum of the whole kidney because some nephrons have lower transport max's than others.
- Examples: glucose, amino acids, phosphate, sulphate

Does Na+ have Transport Maximum?

A uninephrectomized patient with uncontrolled diabetes has a GFR of 90 ml/min, a plasma glucose of 200 mg% (2mg/ml), and a transport max (Tm) shown in the figure. What is the glucose excretion for this patient?

1. 0 mg/min
2. 30 mg/min
3. 60 mg/min
4. 90 mg/min
5. 120 mg/min



Answer: $\text{Filt}_{Glu} = (\text{GFR} \times P_{Glu}) = (90 \times 2) = 180$ mg/min

$\text{Reabs}_{Glu} = T_{max} = 150$ mg/min

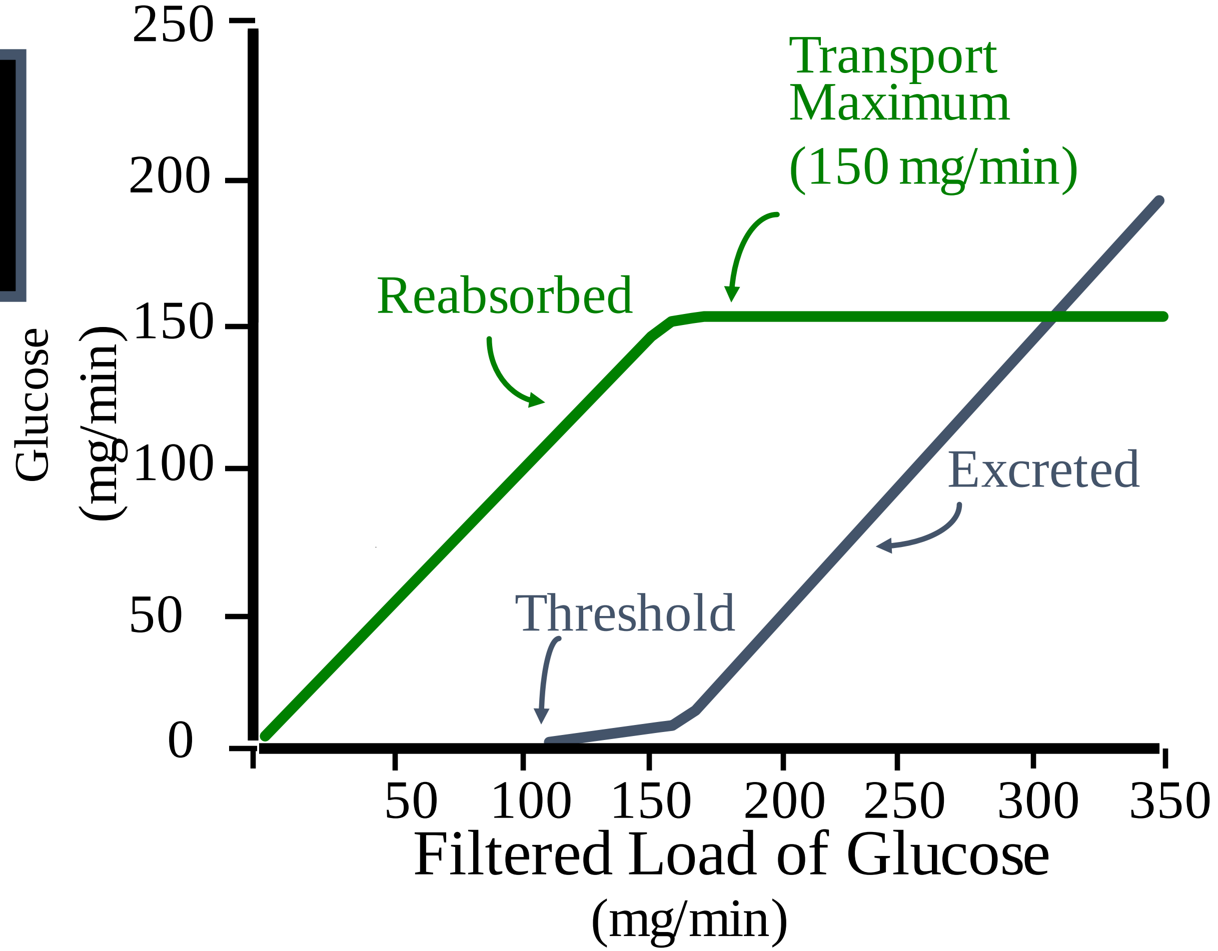
$\text{Excret}_{Glu} = 30$ mg/min

GFR = 90 ml/min

P_{Glu} = 2 mg/ml

T_{max} = 150 mg/min

a. 0 mg/min
b. 30 mg/min
c. 60 mg/min
d. 90 mg/min
e. 120 mg/min



Peritubular Capillary Reabsorption

Reabs = Net Reabs Pressure (NRP) x K_f

= (10 mmHg) x (12.4 ml/min/mmHg)

Reabs = 124 ml/min

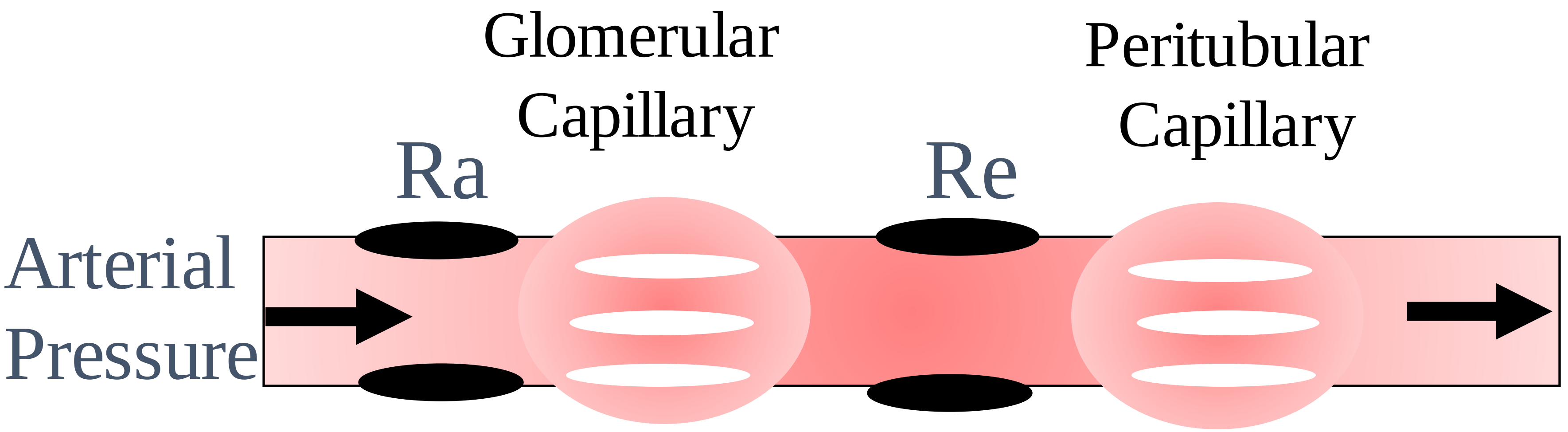
Determinants of Renal Reabsorption

$\uparrow K_f \longrightarrow \uparrow$ Reabsorption

$\uparrow Pc \longrightarrow \downarrow$ Reabsorption

$\uparrow \Pi c \longrightarrow \uparrow$ Reabsorption

Determinants of Renal Reabsorption



↑ Arterial Pressure → ↑ Pc → ↓ Reabs.

↑ Ra → ↓ Pc → ↑ Reabs.

↑ Re → ↓ Pc → ↑ Reabs.

Determinants of Renal Reabsorption

$\uparrow \Pi c \longrightarrow \uparrow$ Reabsorption

$\uparrow$ Plasm. Prot. $\longrightarrow \uparrow \Pi a \longrightarrow \uparrow \Pi c$

$\uparrow$ Filt. Fract. $\longrightarrow \uparrow \Pi c$

Remember

Filt. Fract. = GFR / RPF

Summary:
Determinants of Renal Reabsorption

↑ K_f → ↑ Reabsorption

↑ Pc → ↓ Reabsorption

↓ Ra → ↑ Pc (↓ Reabs)

↓ Re → ↑ Pc (↓ Reabs)

↑ Art. Press → ↑ Pc (↓ Reabs)

↑ Πc → ↑ Reabsorption

↑ Πa → ↑ Πc

↑ Filt. Fract. → ↑ Πc

Effect of increased hydrostatic pressure or decreased colloid osmotic pressure in peritubular capillaries to reduce reabsorption

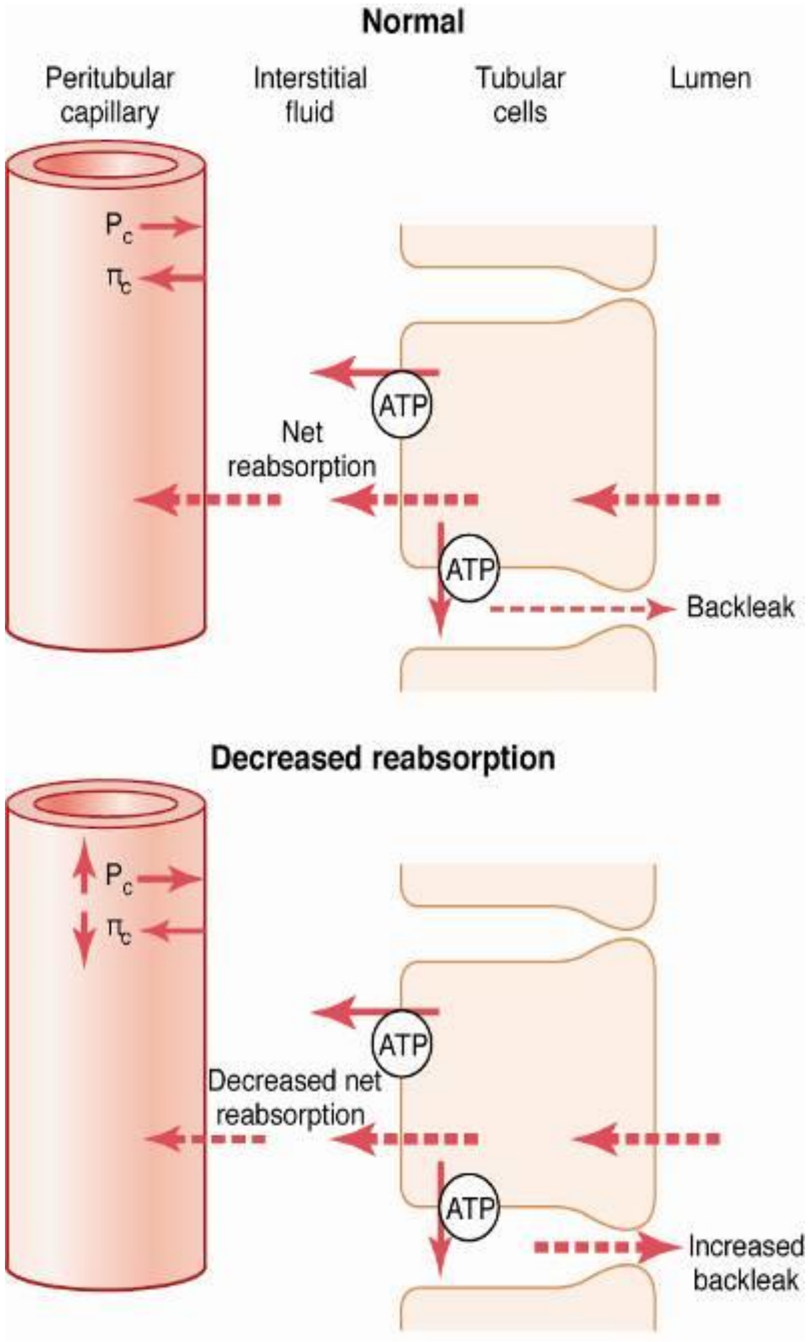
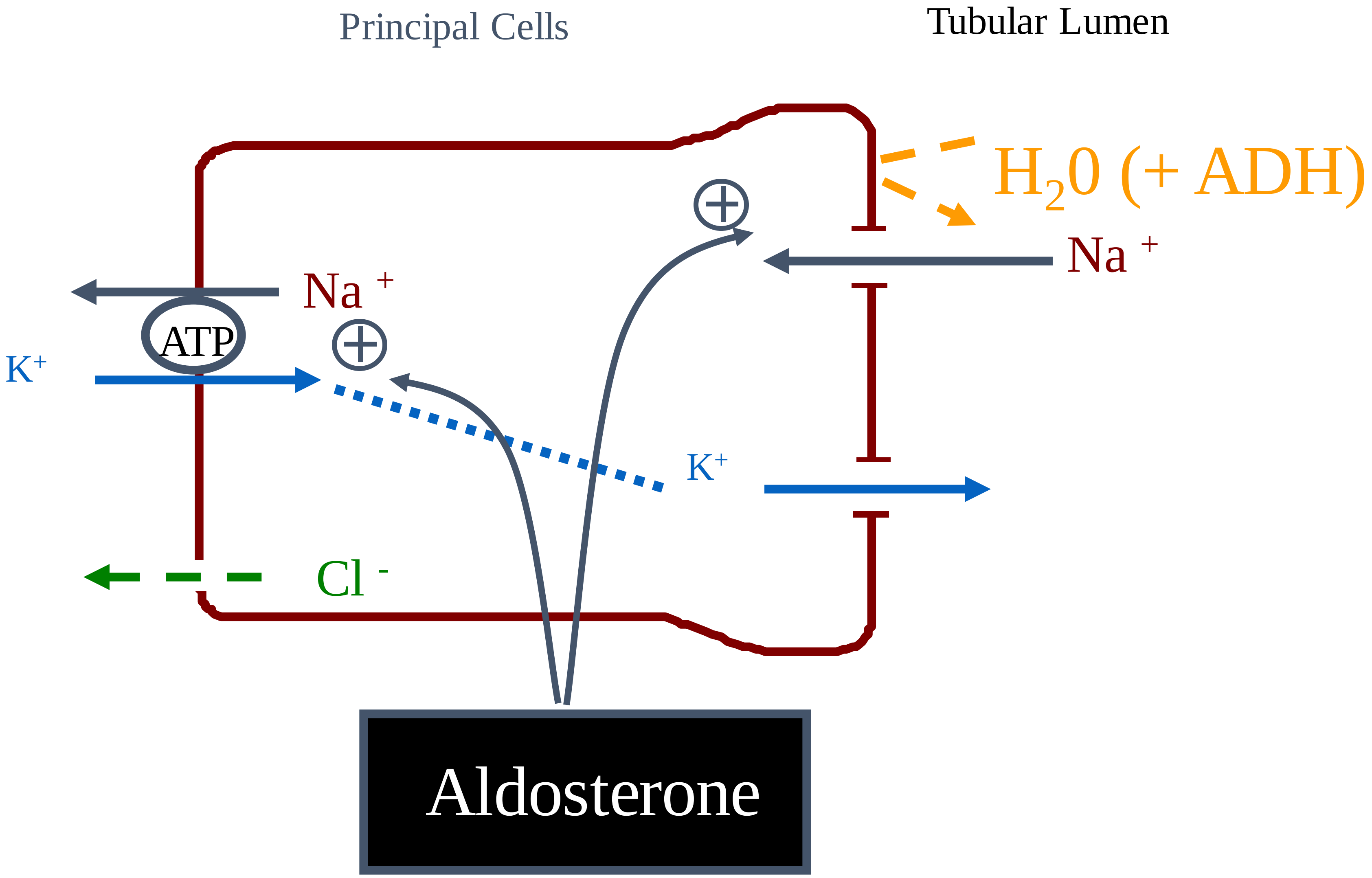


Figure 27-16

Aldosterone actions on late distal, cortical and medullary collecting tubules

- Increases Na^+ reabsorption - principal cells
- Increases K^+ secretion - principal cells
- Increases H^+ secretion - intercalated cells

Late Distal, Cortical and Medullary Collecting Tubules



Clinical Perspective
Abnormal Aldosterone Production

- Excess aldosterone (Primary aldosteronism Conn's syndrome) - Na^+ retention, hypokalemia, alkalosis, hypertension

- Aldosterone deficiency - Addison's disease Na^+ wasting, hyperkalemia, hypotension

Control of Aldosterone Secretion

Factors that increase aldosterone secretion

- Angiotensin II
- Increased K^+
- adrenocorticotrophic hormone (ACTH) (permissive role)

Factors that decrease aldosterone secretion

- Atrial natriuretic factor (ANF)
- Increased Na^+ concentration (osmolality)

Angiotensin II Increases Na^+ and Water Reabsorption

- Stimulates aldosterone secretion
- Directly increases Na^+ reabsorption
  (proximal, loop, distal, collecting tubules)
- Constricts efferent arterioles
  - decreases peritubular capillary hydrostatic pressure
  - increases filtration fraction, which increases peritubular colloid osmotic pressure)

Audio-Visual Aid [Renin Angiotensin Aldosterone System - YouTube]

Angiotensin II increases renal tubular sodium reabsorption

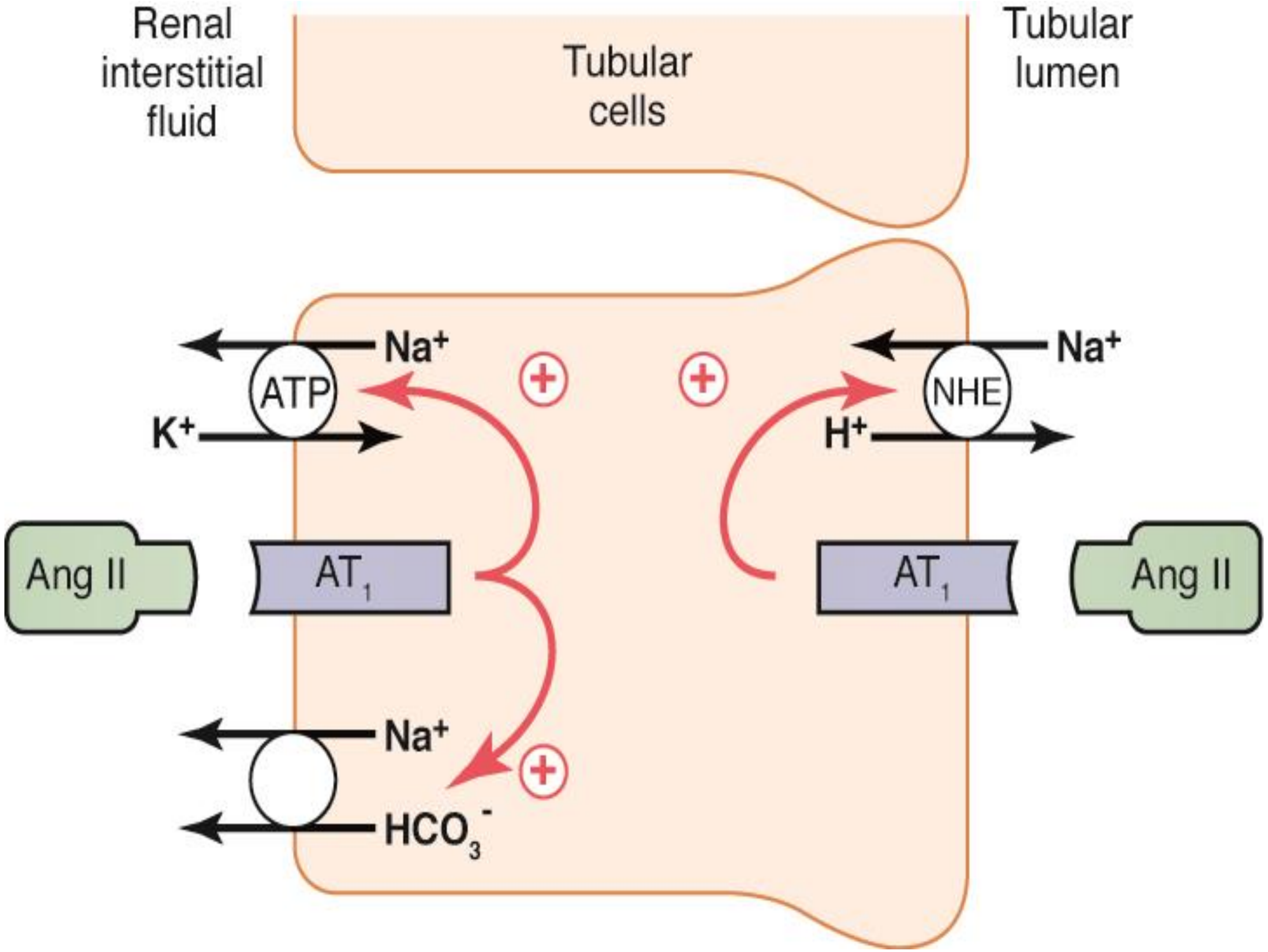
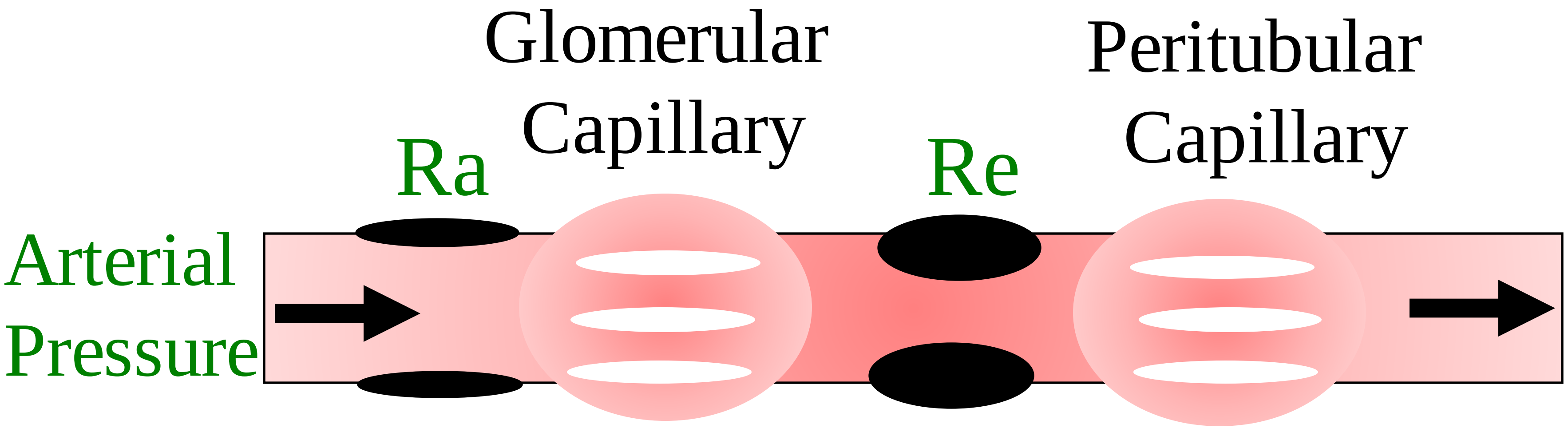


Figure 27-17

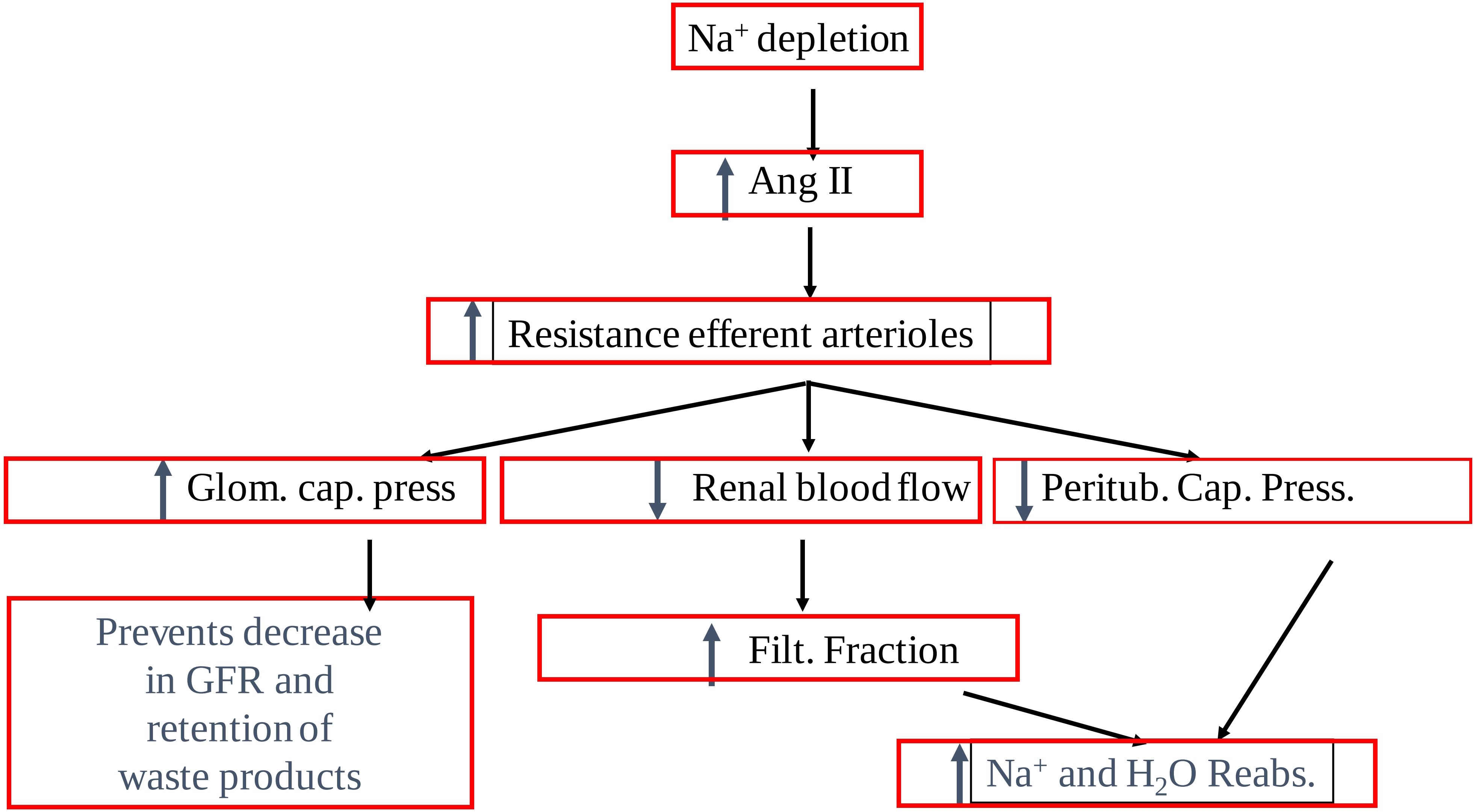
Effect of Angiotensin II on Peritubular Capillary Dynamics



↑ Ang II → ↑ Re → ↓ Pc (peritubular cap. press.)

↓ renal blood flow → ↑ FF → ↑ Πc

Ang II constriction of efferent arterioles causes Na$^+$ and water retention and maintains excretion of waste products



Na$^+$ depletion

↑ Ang II

↑ Resistance efferent arterioles

↑ Glom. cap. press

↓ Renal blood flow

↓ Peritub. Cap. Press.

Prevents decrease in GFR and retention of waste products

↑ Filt. Fraction

↑ Na$^+$ and H_2O Reabs.

Angiotensin II blockade decreases Na$^+$ reabsorption and blood pressure

- ACE inhibitors (captopril, benazipril, ramipril)
- Ang II antagonists (losartan, candesartin, irbesartan)
- Renin inhibitors (aliskirin)
  - decrease aldosterone
  - directly inhibit Na$^+$ reabsorption
  - decrease efferent arteriolar resistance

⇩

Natriuresis and Diuresis + ↓ Blood Pressure

Antidiuretic Hormone (ADH)

- Secreted by posterior pituitary
- Increases H_2O permeability and reabsorption in distal and collecting tubules
- Allows differential control of H_2O and solute excretion
- Important controller of extracellular fluid osmolarity

ADH synthesis in
the magnocellular
neurons of hypothalamus,
release by the posterior
pituitary, and action
on the kidneys

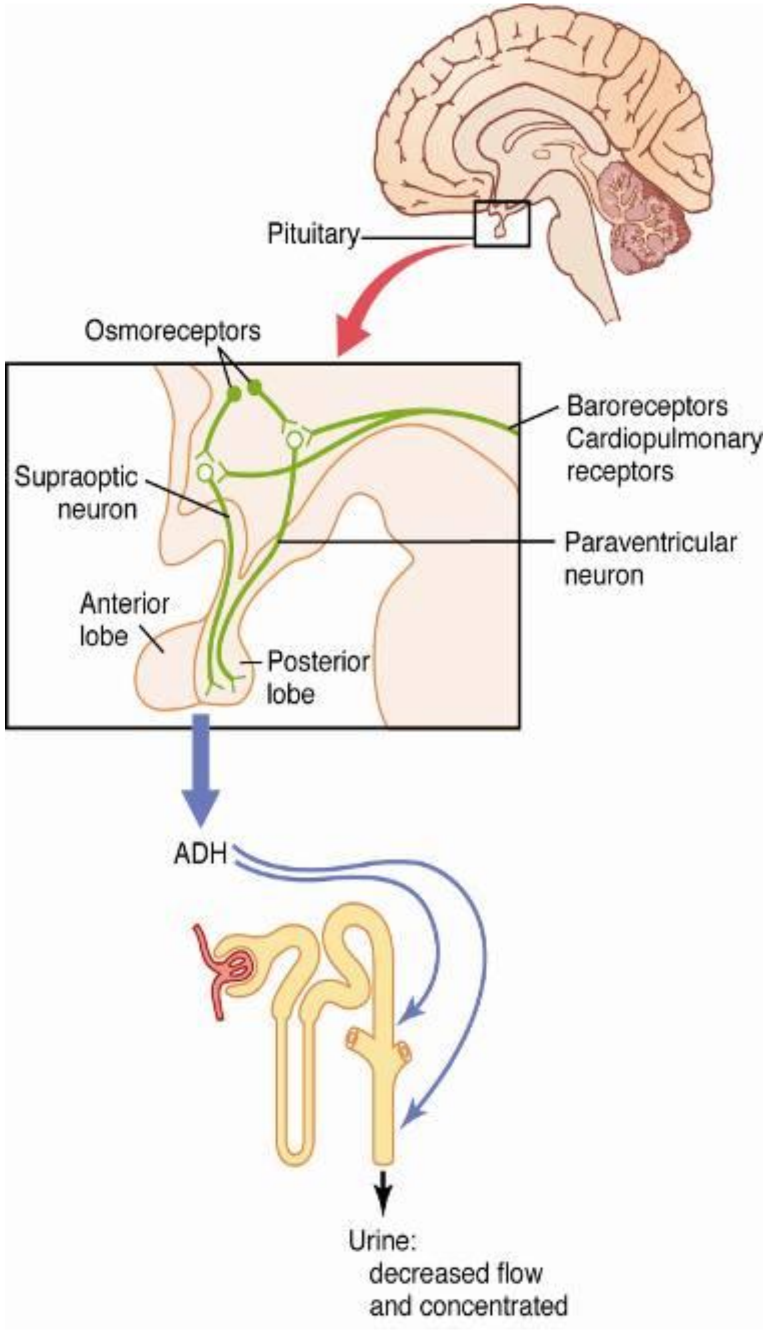


Figure 28-10

Mechanism of action of ADH in distal and collecting tubules

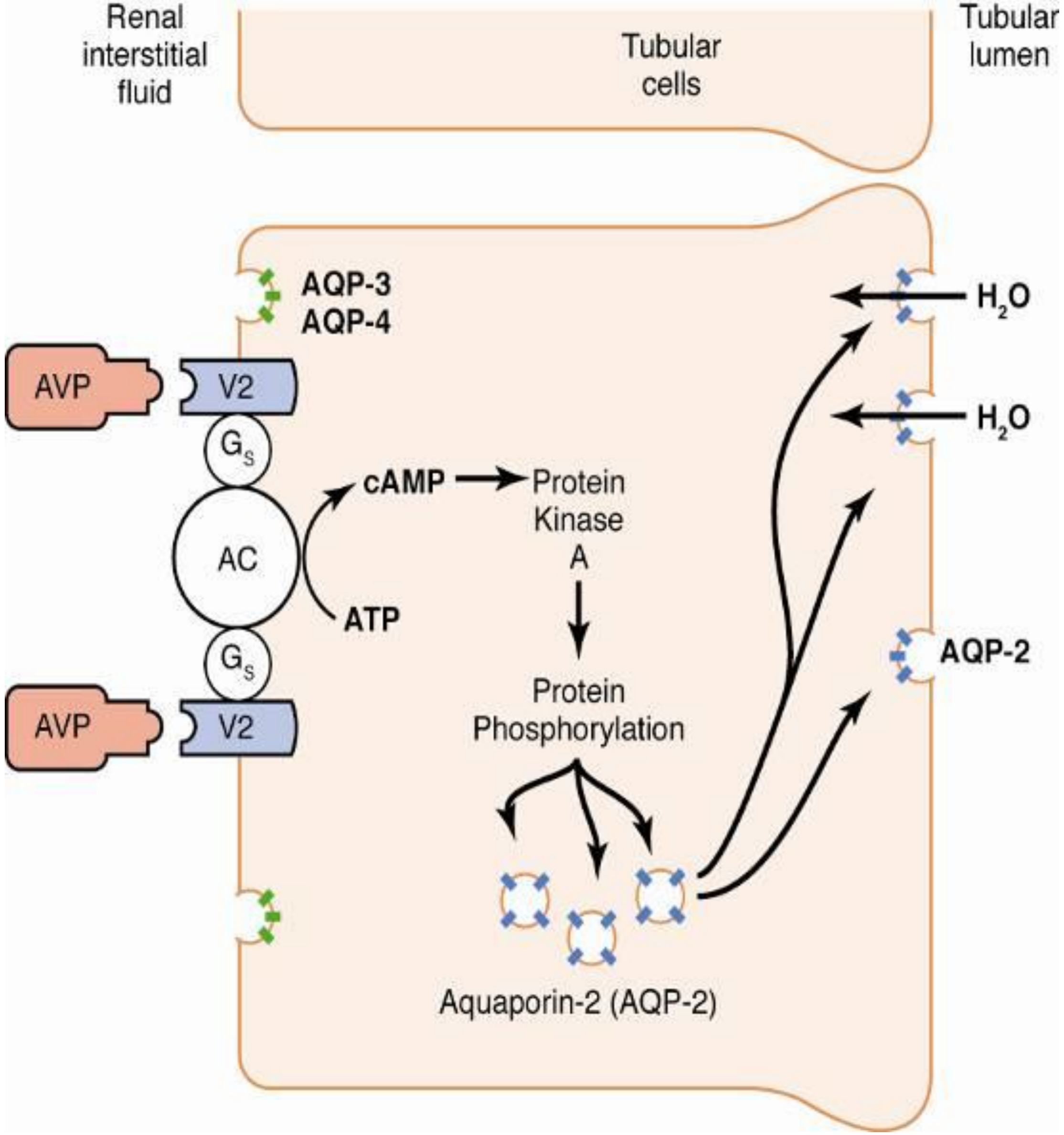
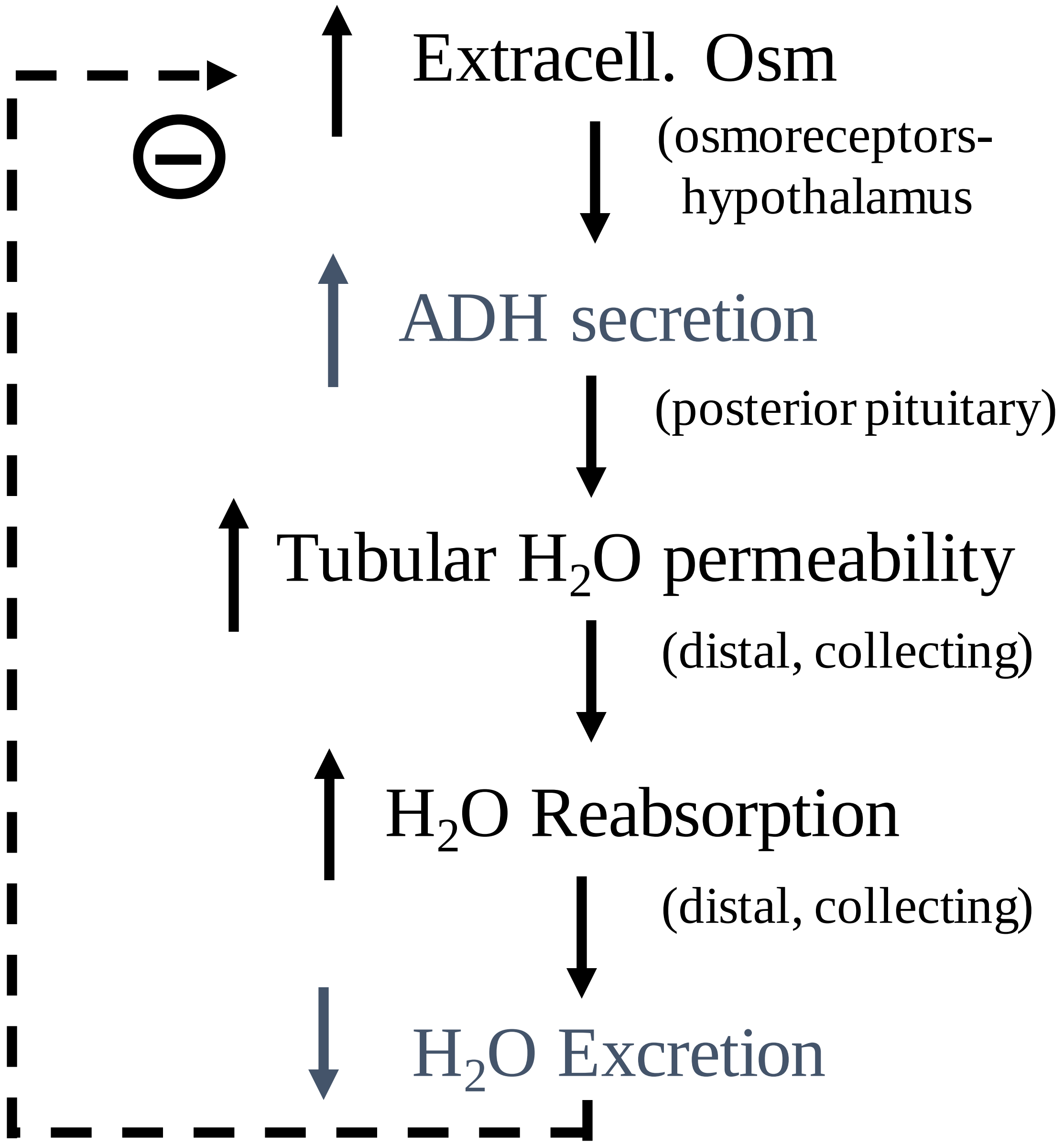


Figure 28-18

Feedback Control of Extracellular Fluid Osmolarity by ADH



↑ Extracell. Osm

(osmoreceptors-
hypothalamus

↑ ADH secretion

(posterior pituitary)

↑ Tubular H_2O permeability

(distal, collecting)

↑ H_2O Reabsorption

(distal, collecting)

↓ H_2O Excretion

Clinical Perspective

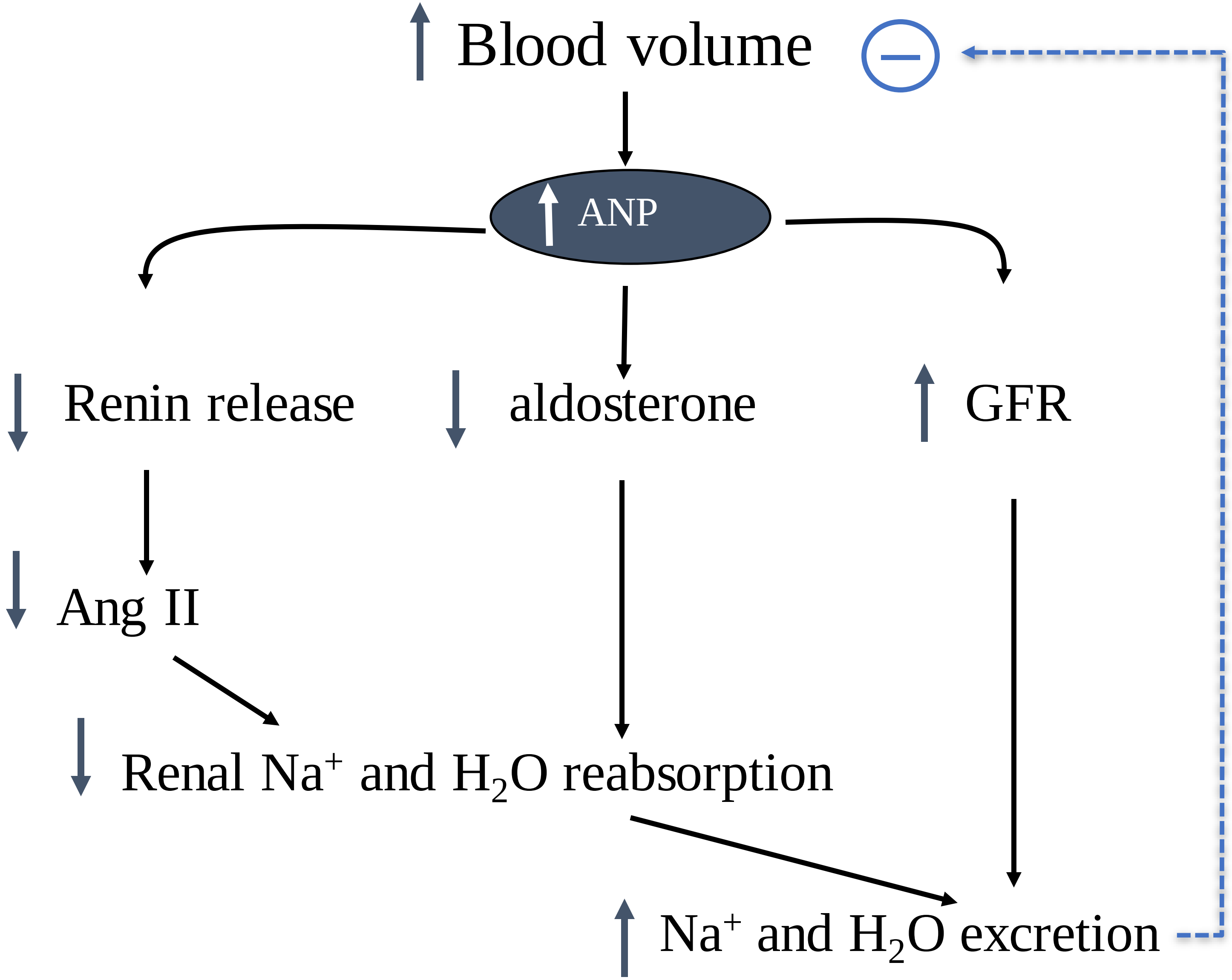
Abnormalities of ADH

- Inappropriate ADH syndrome (excess ADH)
  - decreased plasma osmolarity, hyponatremia
- “Central” Diabetes insipidus (insufficient ADH)
  - increased plasma osmolarity, hypernatremia, excess thirst

Atrial natriuretic peptide increases Na^+ excretion

- Secreted by cardiac atria in response to stretch (increased blood volume)
- Directly inhibits Na^+ reabsorption
- Inhibits renin release and aldosterone formation
- Increases GFR
- Helps to minimize blood volume expansion

Atrial Natriuretic Peptide (ANP)



↑ Blood volume ⊖

↑ ANP

↓ Renin release

↓ aldosterone

↑ GFR

↓ Ang II

↓ Renal Na^+ and H_2O reabsorption

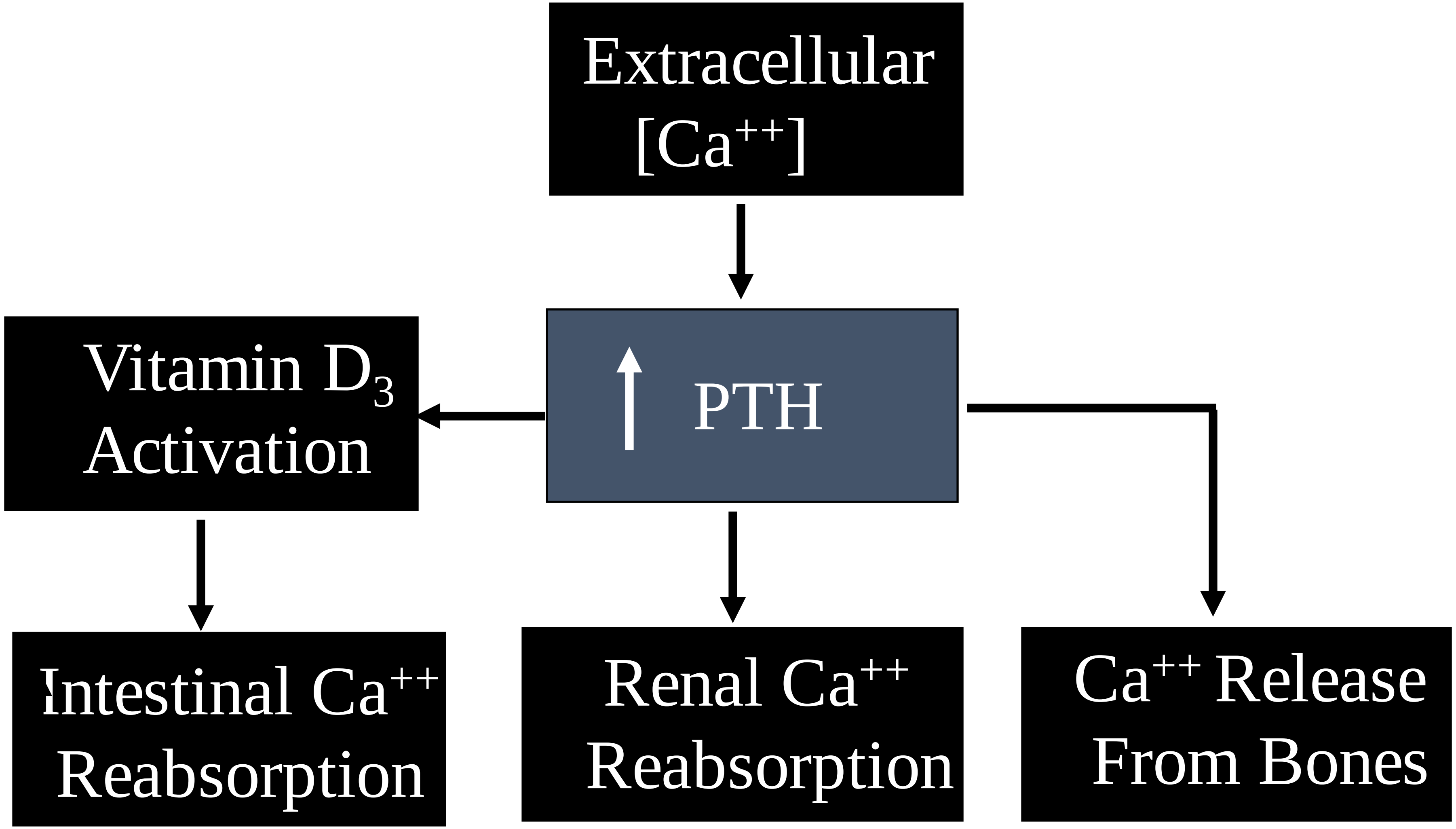
↑ Na^+ and H_2O excretion

Parathyroid hormone increases renal Ca^{++} reabsorption

- Released by parathyroids in response to decreased extracellular Ca^{++}
- Increases Ca^{++} reabsorption by kidneys
- Increases Ca^{++} reabsorption by gut
- Decreases phosphate reabsorption
- Helps to increase extracellular Ca^{++}

(see chapter 29)

Control of Ca^{++} by Parathyroid Hormone



Extracellular $[Ca^{++}]$

↑ PTH

Vitamin D_3 Activation

Intestinal Ca^{++} Reabsorption

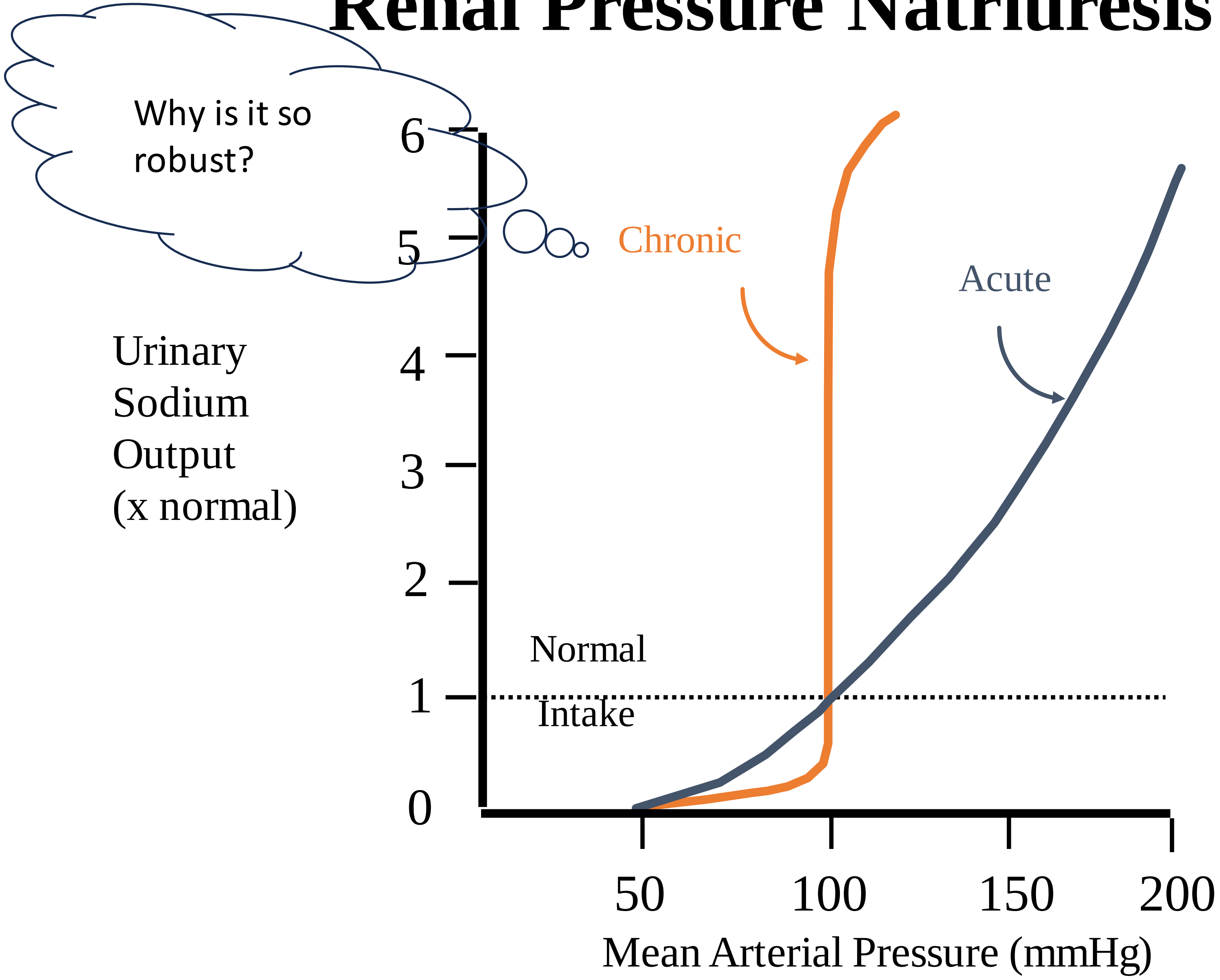
Renal Ca^{++} Reabsorption

Ca^{++} Release From Bones

Sympathetic nervous system increases Na^+ reabsorption

- Directly stimulates Na^+ reabsorption
- Stimulates renin release
- Decreases GFR and renal blood flow (only a high levels of sympathetic stimulation)

Renal Pressure Natriuresis



Why is it so robust?

Answer

Increased Arterial Pressure Decreases Na^+ Reabsorption (Pressure Natriuresis)

- Increased peritubular capillary hydrostatic pressure
- Decreased renin and aldosterone
- Increased release of intrarenal natriuretic factors
  - prostaglandins
  - EDRF

Osmotic Effects on Reabsorption

- Water is reabsorbed only by osmosis
- Increasing the amount of unreabsorbed solutes in the tubules decreases water reabsorption

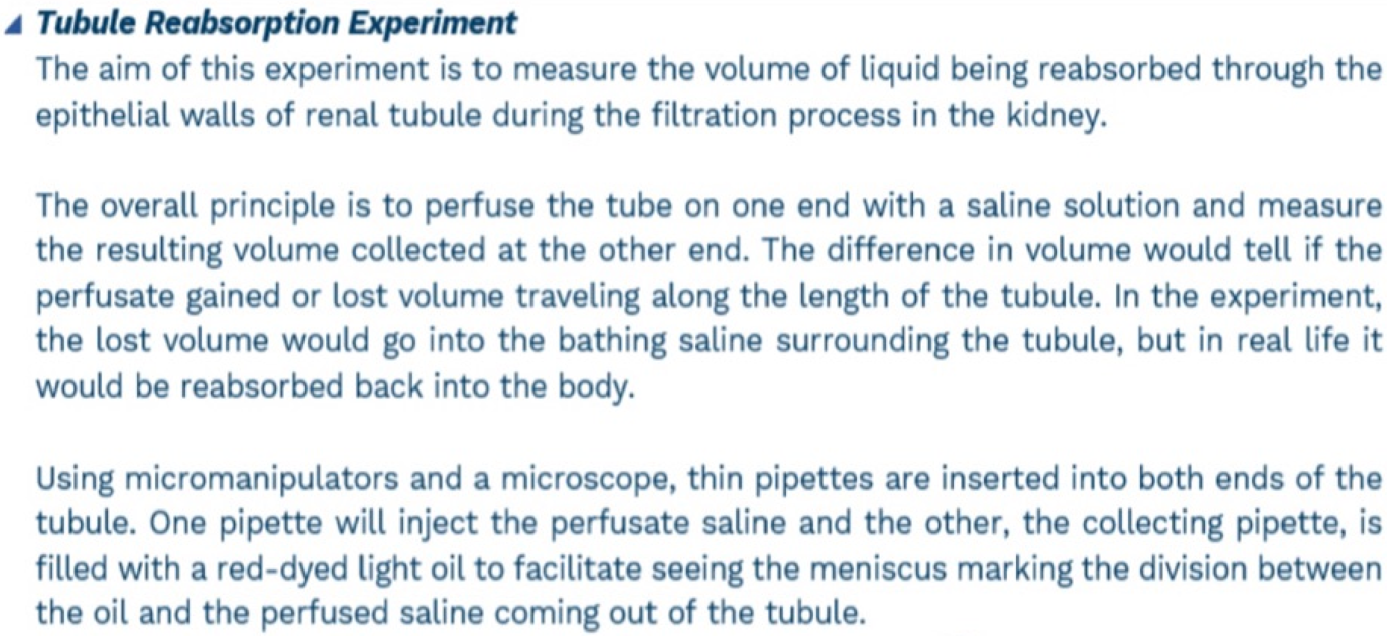
i.e. diabetes mellitus : unreabsorbed glucose in tubules causes diuresis and water loss

i.e. osmotic diuretics (mannitol)

Assessing Kidney Function

- Plasma concentration of waste products
  (e.g. BUN, creatinine)
- Urine specific gravity, urine concentrating ability;
- Urinalysis test reagent strips (protein, glucose, etc)
- Biopsy
- Albumin excretion (microalbuminuria)
- Isotope renal scans
- Imaging methods (e.g. MRI, PET, arteriograms,
  iv pyelography, ultrasound etc)
- Clearance methods (e.g. 24-hr creatinine clearance)
- etc

Lab experiments to study reabsorption

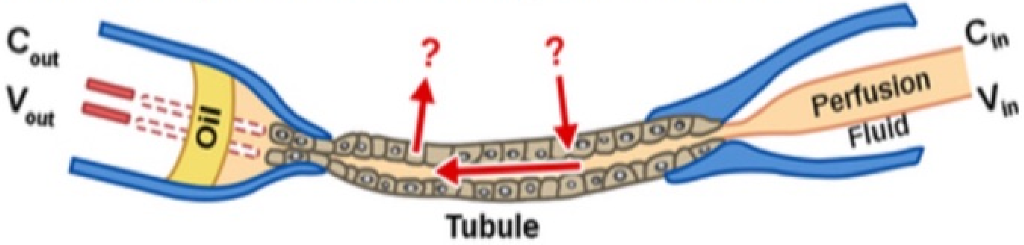


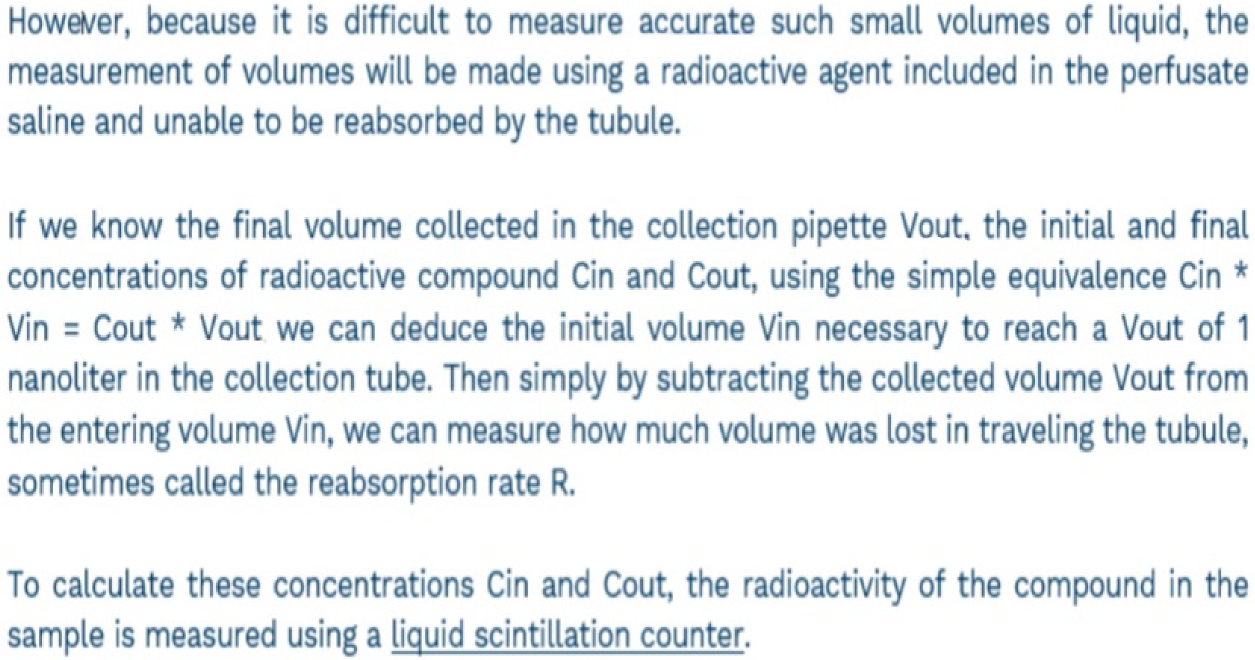
Tubule Reabsorption Experiment

The aim of this experiment is to measure the volume of liquid being reabsorbed through the epithelial walls of renal tubule during the filtration process in the kidney.

The overall principle is to perfuse the tube on one end with a saline solution and measure the resulting volume collected at the other end. The difference in volume would tell if the perfusate gained or lost volume traveling along the length of the tubule. In the experiment, the lost volume would go into the bathing saline surrounding the tubule, but in real life it would be reabsorbed back into the body.

Using micromanipulators and a microscope, thin pipettes are inserted into both ends of the tubule. One pipette will inject the perfusate saline and the other, the collecting pipette, is filled with a red-dyed light oil to facilitate seeing the meniscus marking the division between the oil and the perfused saline coming out of the tubule.





However, because it is difficult to measure accurate such small volumes of liquid, the measurement of volumes will be made using a radioactive agent included in the perfusate saline and unable to be reabsorbed by the tubule.

If we know the final volume collected in the collection pipette Vout, the initial and final concentrations of radioactive compound Cin and Cout, using the simple equivalence Cin * Vin = Cout * Vout we can deduce the initial volume Vin necessary to reach a Vout of 1 nanoliter in the collection tube. Then simply by subtracting the collected volume Vout from the entering volume Vin, we can measure how much volume was lost in traveling the tubule, sometimes called the reabsorption rate R.

To calculate these concentrations Cin and Cout, the radioactivity of the compound in the sample is measured using a liquid scintillation counter.

Link To Recording of Clearance and GFR Calculation

https://fisjo-my.sharepoint.com/:v:/g/personal/e_zayadneh_ju_edu_jo/EVfxrMv5fDZHgWF5wU3y3x0BW4Y-3tEaRCkc6iRxRnZ7rQ?e=LosKcU

Clearance

- “Clearance” describes the rate at which substances are removed (cleared) from the plasma.

- Renal clearance of a substance is the volume of plasma completely cleared of a substance
  per min by the kidneys.

Clearance Technique

Renal clearance (Cs) of a substance is the volume of plasma completely cleared of a substance per min.

$$Cs \times Ps = Us \times V$$

$$Cs = \frac{Us \times V}{Ps} = \frac{\text{urine excretion rate}}{\text{Plasma conc. s}}$$

Where : Cs = clearance of substance S

Ps = plasma conc. of substance S

Us = urine conc. of substance S

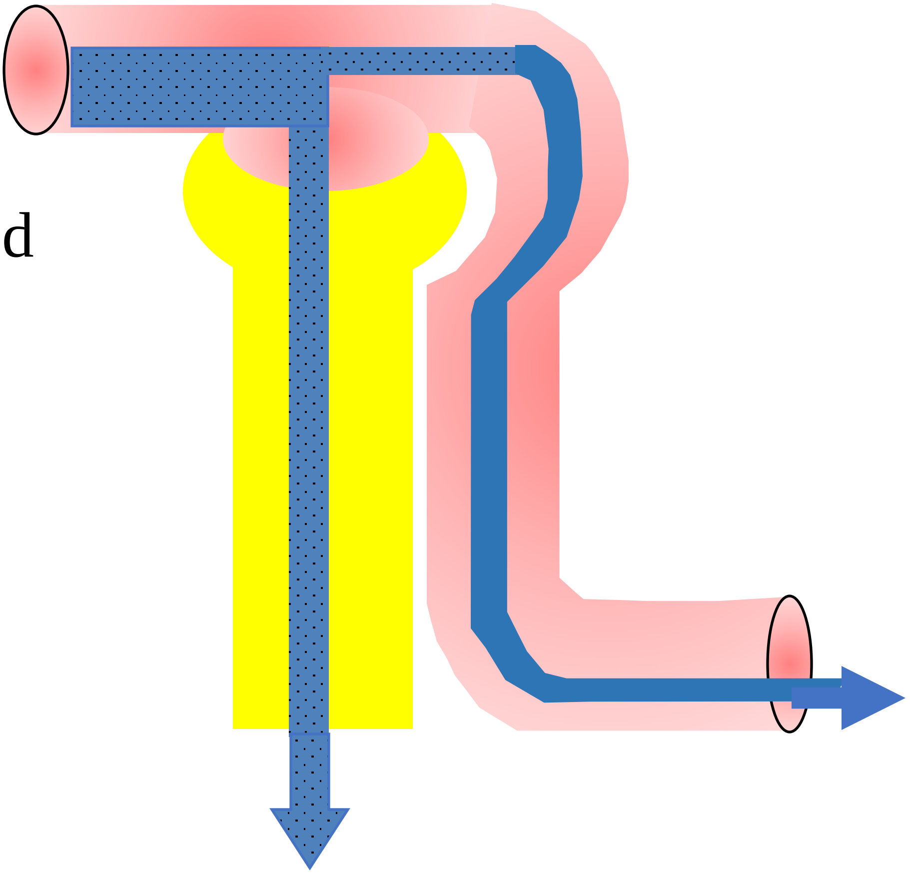
V = urine flow rate

Clearances of Different Substances

Substance	Clearance (ml/min)
glucose	0
albumin	0
sodium	0.9
urea	70
inulin	125
creatinine	140
PAH	600

Use of Clearance to Measure GFR

For a substance that is freely filtered, but not reabsorbed or secreted (inulin, ^{125}I-iothalamate, creatinine), renal clearance is equal to GFR



amount filtered = amount excreted

$$GFR \times P_{in} = U_{in} \times V$$

$$GFR = \frac{U_{in} \times V}{P_{in}}$$

Calculate the GFR from the following data:

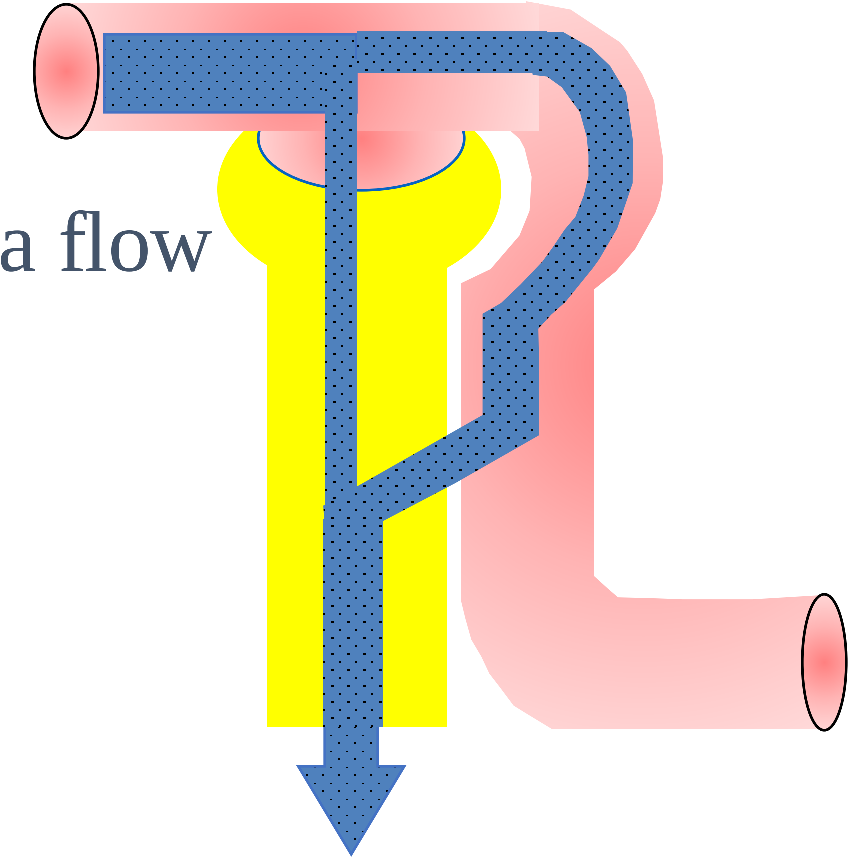
P_{inulin} = 1.0 mg / 100ml
U_{inulin} = 125 mg/100 ml
Urine flow rate = 1.0 ml/min

$$GFR = C_{inulin} = \frac{U_{in} \text{ x } V}{P_{in}}$$

$$GFR = \frac{125 \text{ x } 1.0}{1.0} = 125 \text{ ml/min}$$

Theoretically, if a substance is completely cleared from the plasma, its clearance rate would equal renal plasma flow

Cx = renal plasma flow



Paraminohippuric acid (PAH) is freely filtered and secreted and is almost completely cleared from the renal plasma

1. amount enter kidney =

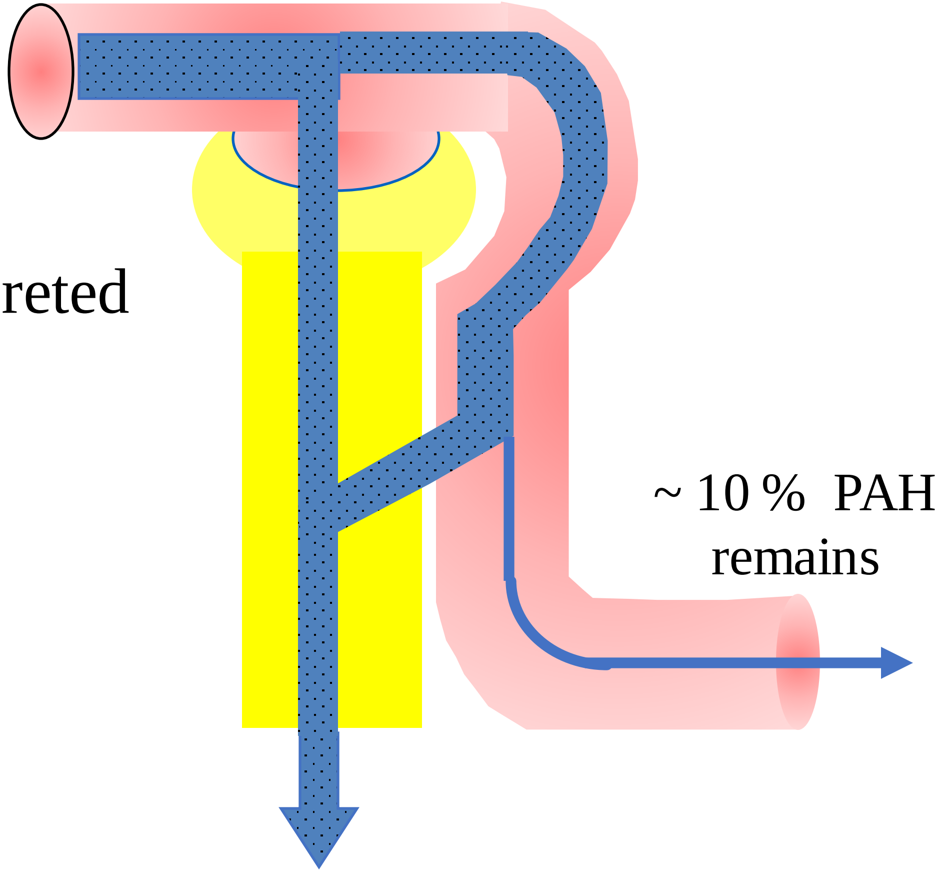
$\text{RPF} \times P_{PAH}$

2. amount entered ≅ amount excreted

3. $\text{ERPF} \times P_{pah} = U_{PAH} \times V$

$$= \frac{U_{PAH} \times V}{P_{PAH}}$$

ERPF = Clearance PAH



ERPF=estimated renal plasma flow

To calculate <u>actual</u> RPF , one must correct for incomplete extraction of PAH

$A_{PAH} = 1.0$

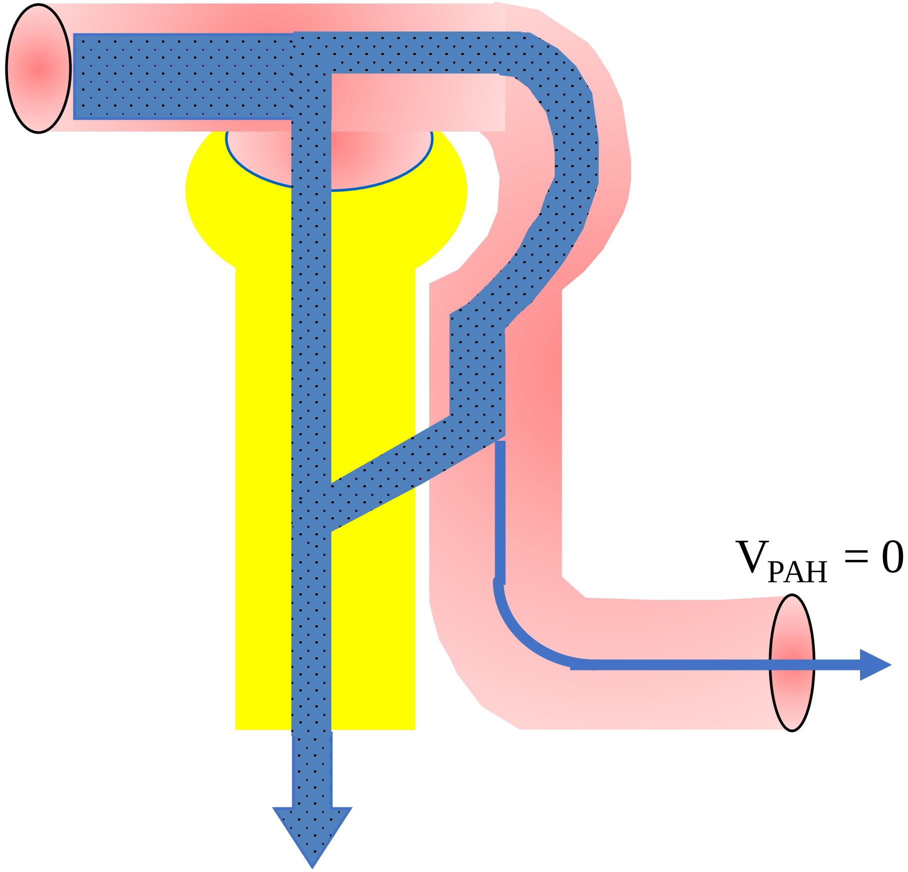
$$E_{PAH} = \frac{A_{PAH} - V_{PAH}}{A_{PAH}}$$

$$= \frac{1.0 - 0.1}{1.0} = 0.9$$

normally, $E_{PAH} = 0.9$

i.e PAH is 90 % extracted

$$RPF = \frac{ERPF}{E_{PAH}}$$

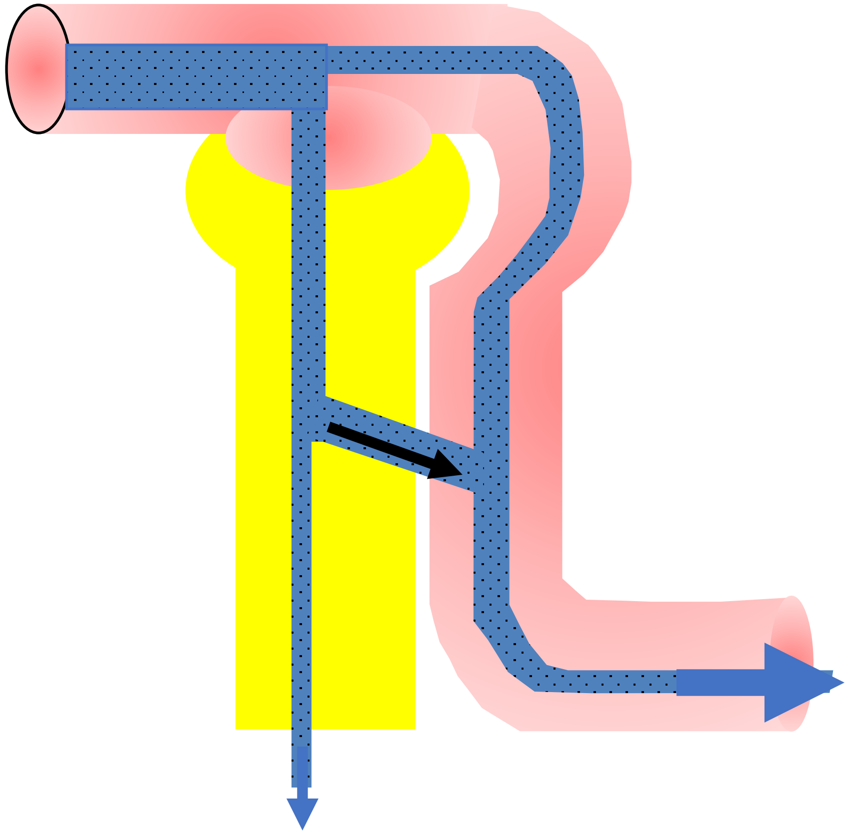


$V_{PAH} = 0.1$

Calculation of Tubular Reabsorption

Reabsorption = Filtration -Excretion

Filt s = GFR x Ps

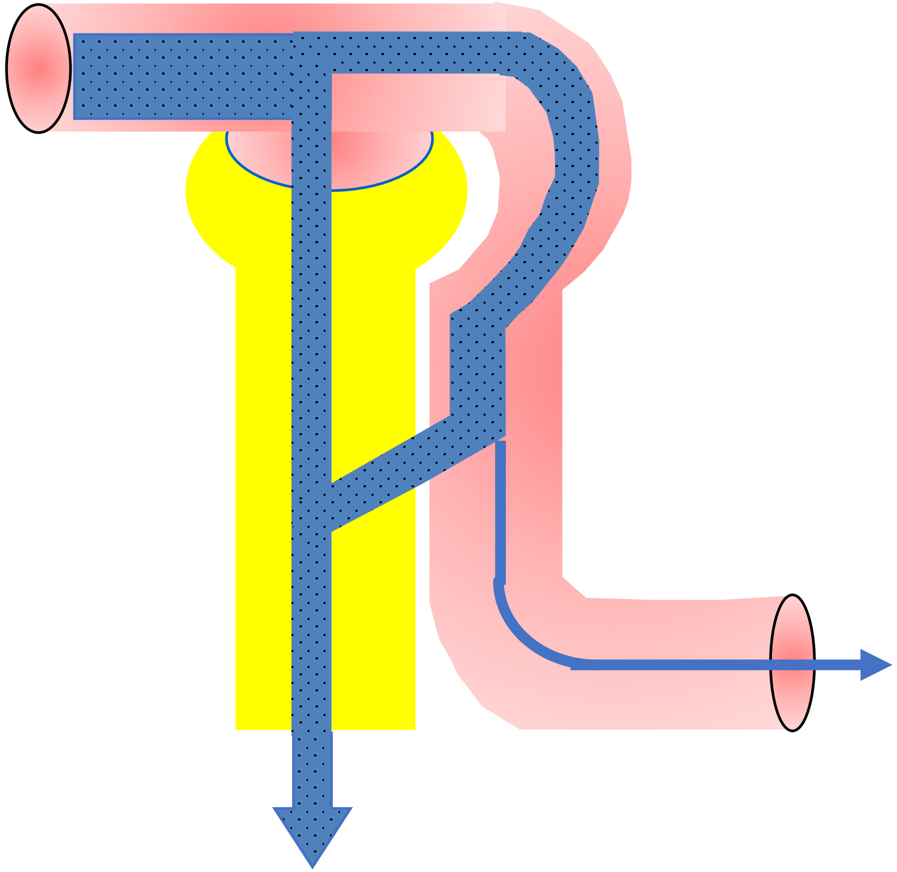


Excret s = Us x V

Calculation of Tubular Secretion

Secretion = Excretion - Filtration

Filt s = GFR x Ps



Excret s = Us x V

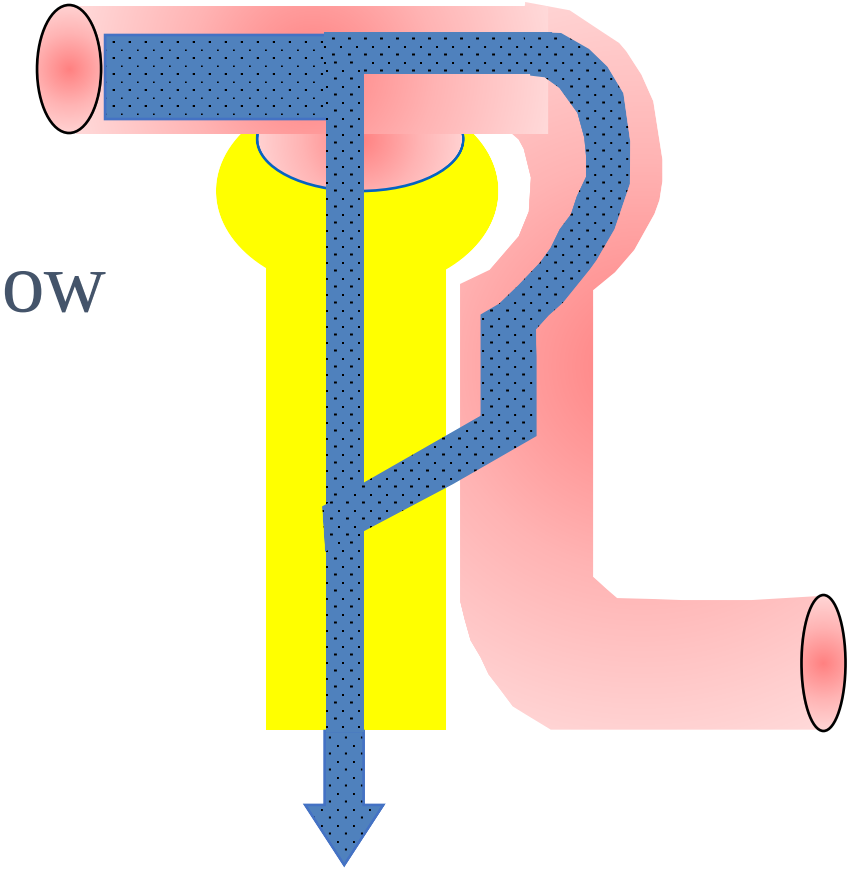
Question

The maximum possible clearance rate of a substance that is completely cleared from the plasma by the kidneys would be equal to

1. glomerular filtration rate
2. the filtered load of the substance
3. urine excretion rate of the substance
4. renal plasma flow
5. none of the above

Use of Clearance to Estimate Renal Plasma Flow

Theoretically, if a substance is completely cleared from the plasma, its clearance rate would equal renal plasma flow



Cx = renal plasma flow

Clearances of Different Substances

Substance	Clearance (ml/min
inulin	125
PAH	600
glucose	0
sodium	0.9
urea	70

Clearance of inulin (C_{in}) = GFR

if Cx < Cin : indicates reabsorption of x

if Cx > Cin : indicates secretion of x

Clearance creatinine (C_{creat}) ~ 140 (used to estimate GFR)

Clearance of PAH (C_{pah}) ~ effective renal plasma flow

Effect of reducing GFR by 50 % on serum creatinine concentration and creatinine excretion rate

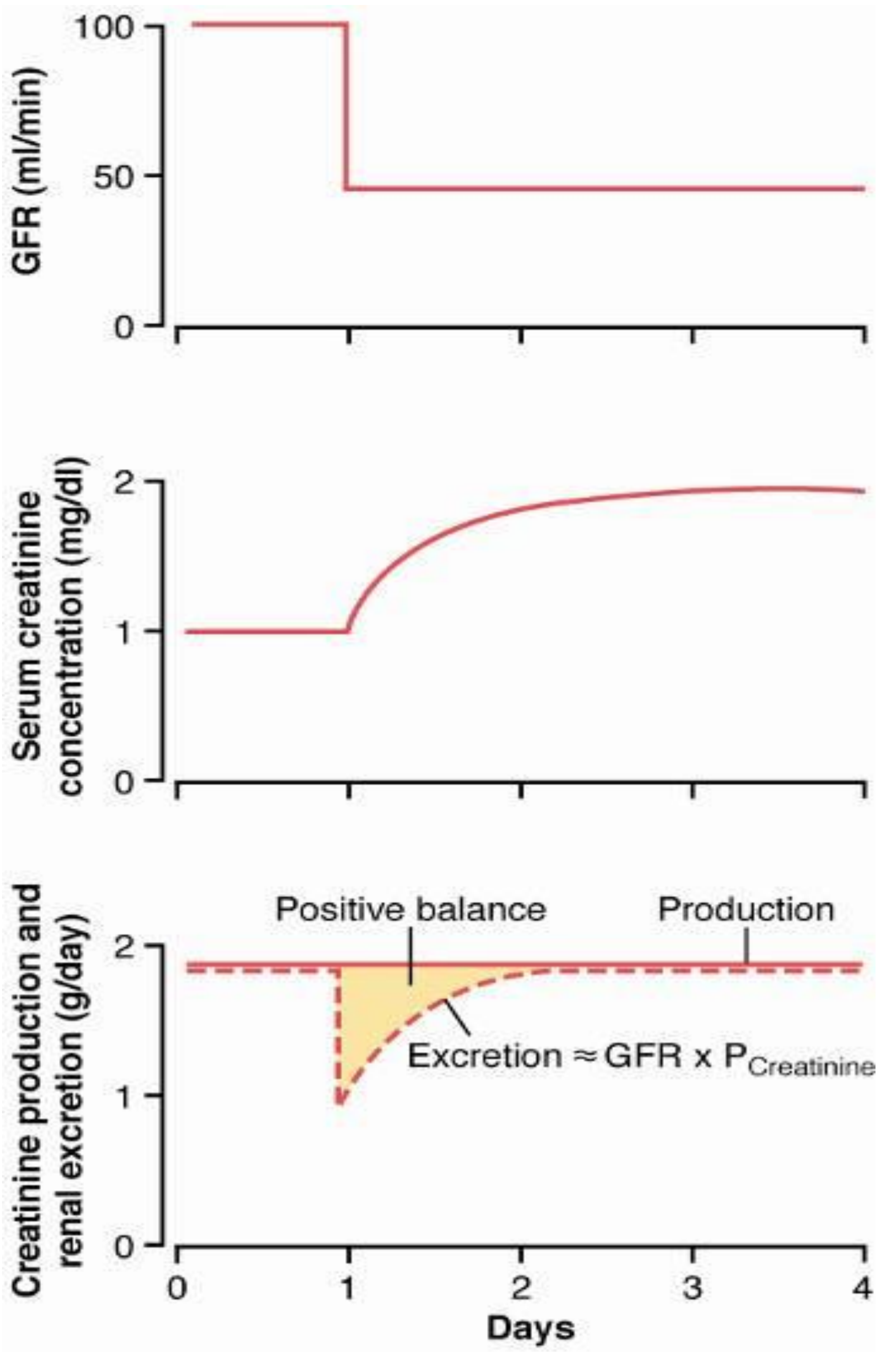


Figure 27-20

True or False?

Reduction of GFR by 50 % will increase serum creatinine to double while, creatinine excretion rate will remain the same as normal in steady state conditions

✓

Plasma creatinine can be used to estimate changes in GFR

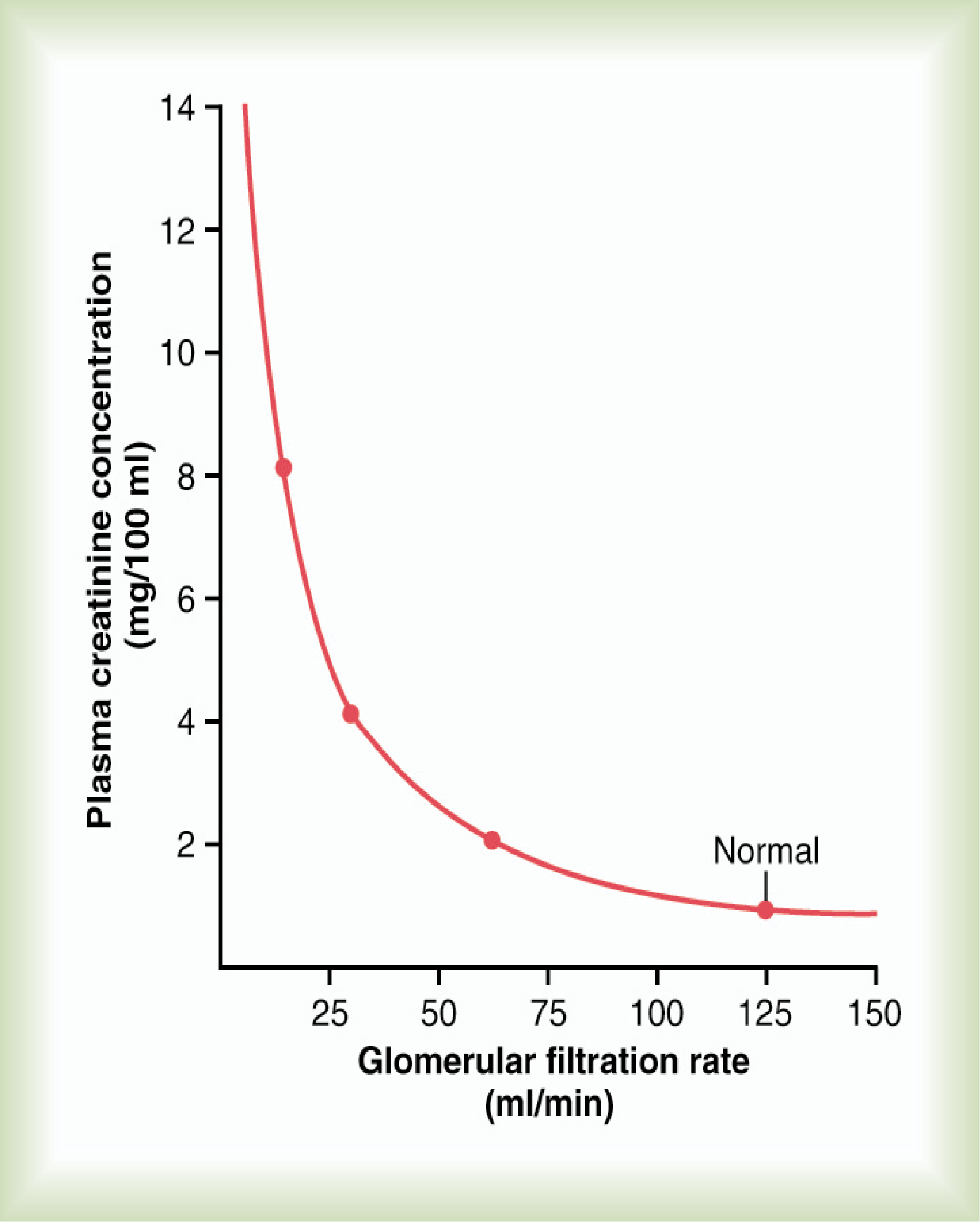


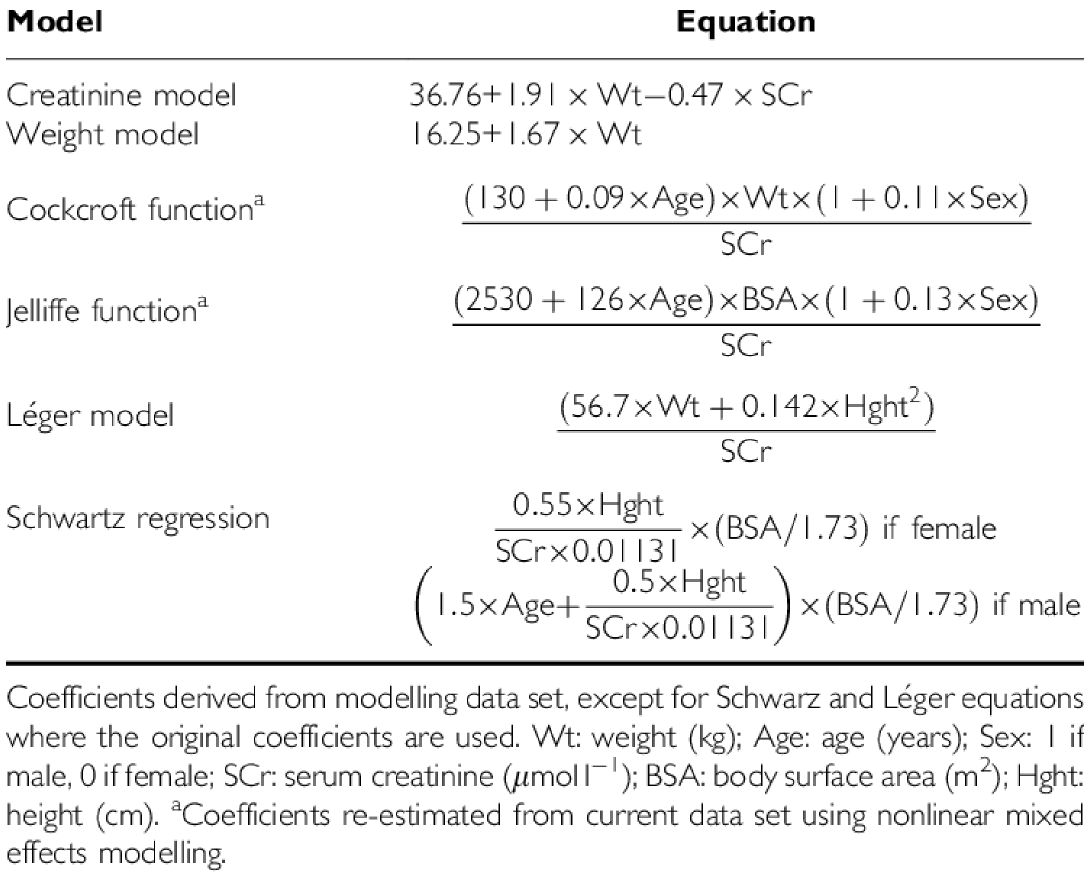
Figure 27-21

Clinical Perspective

Clinical GFR estimation equations using GFR

Online calculator:

[eGFR Calculator | National Kidney Foundation]

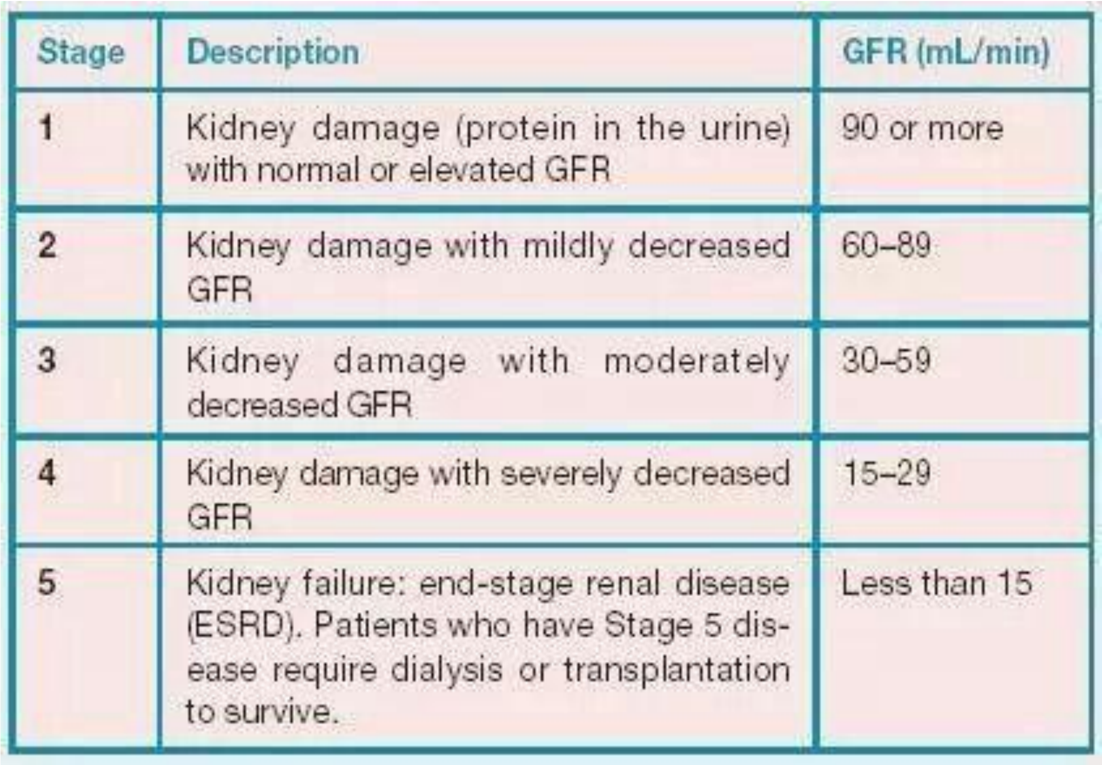


Model	Equation
Creatinine model	$36.76+1.91 \times \mathrm{Wt}-0.47 \times \mathrm{SCr}$
Weight model	$16.25+1.67 \times \mathrm{Wt}$
Cockcroft function[a]	$\dfrac{(130+0.09\times \mathrm{Age})\times \mathrm{Wt}\times(1+0.11\times \mathrm{Sex})}{\mathrm{SCr}}$
Jelliffe function[a]	$\dfrac{(2530+126\times \mathrm{Age})\times \mathrm{BSA}\times(1+0.13\times \mathrm{Sex})}{\mathrm{SCr}}$
Léger model	$\dfrac{(56.7\times \mathrm{Wt}+0.142\times \mathrm{Hght}^2)}{\mathrm{SCr}}$
Schwartz regression	$\dfrac{0.55\times \mathrm{Hght}}{\mathrm{SCr}\times 0.01131}\times(\mathrm{BSA}/1.73)$ if female $\left(1.5\times \mathrm{Age}+\dfrac{0.5\times \mathrm{Hght}}{\mathrm{SCr}\times 0.01131}\right)\times(\mathrm{BSA}/1.73)$ if male

Coefficients derived from modelling data set, except for Schwarz and Léger equations where the original coefficients are used. Wt: weight (kg); Age: age (years); Sex: 1 if male, 0 if female; SCr: serum creatinine (μmol l^{-1}); BSA: body surface area (m^2); Hght: height (cm). [a]Coefficients re-estimated from current data set using nonlinear mixed effects modelling.

Clinical Perspective

Chronic kidney disease evaluation by GFR



Stage	Description	GFR (mL/min)
1	Kidney damage (protein in the urine) with normal or elevated GFR	90 or more
2	Kidney damage with mildly decreased GFR	60–89
3	Kidney damage with moderately decreased GFR	30–59
4	Kidney damage with severely decreased GFR	15–29
5	Kidney failure: end-stage renal disease (ESRD). Patients who have Stage 5 disease require dialysis or transplantation to survive.	Less than 15