Renal Tubular Reabsorption and Secretion-I

Unit V

Chapter 28

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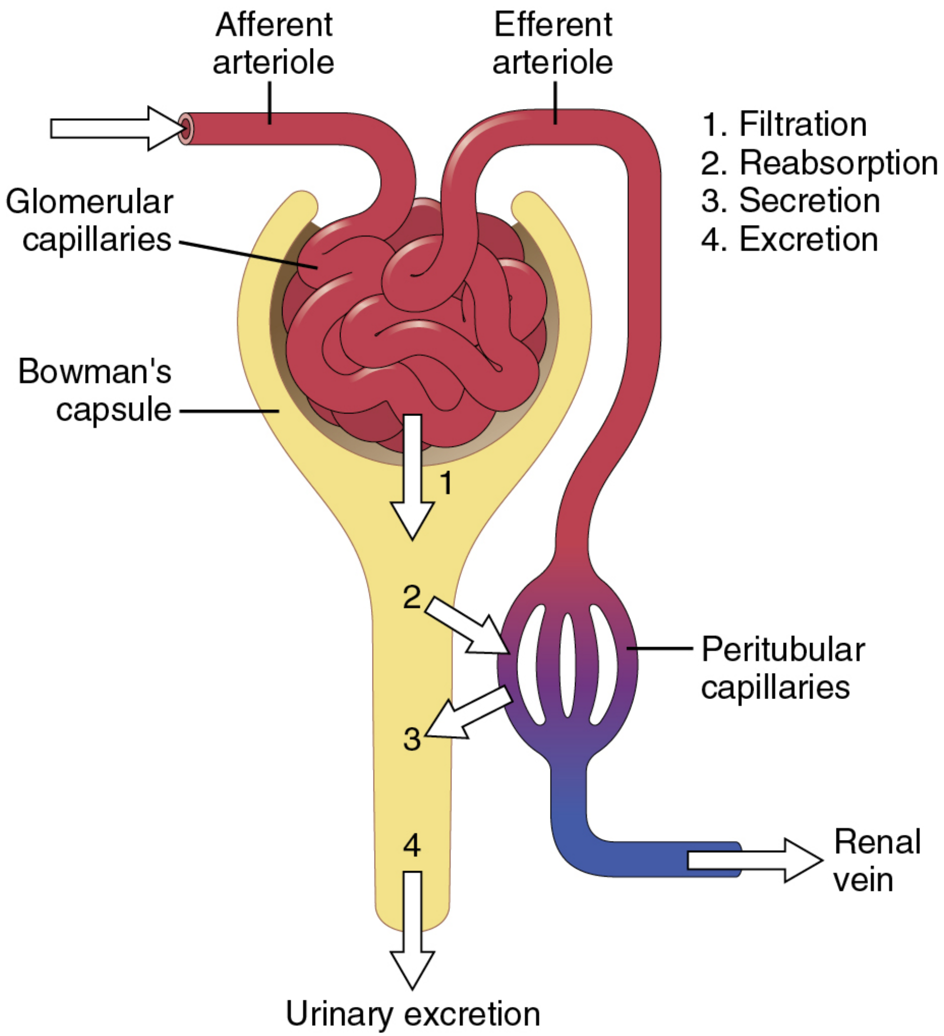
Basic Mechanisms of Urine Formation



Excretion = Filtration – Reabsorption + Secretion

Glomerular filtration

- Filtration = GFR × Plasma concentration
- Assuming that substance is not bound to plasma proteins

large quantities

small quantities

Table 28-1 Filtration, Reabsorption, and Excretion Rates of Different Substances by the Kidneys

	Amount Filtered	Amount Reabsorbed	Amount Excreted	% of Filtered Load Reabsorbed
Glucose (g/day)	180	180	0	100
Bicarbonate (mEq/day)	4320	4318	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

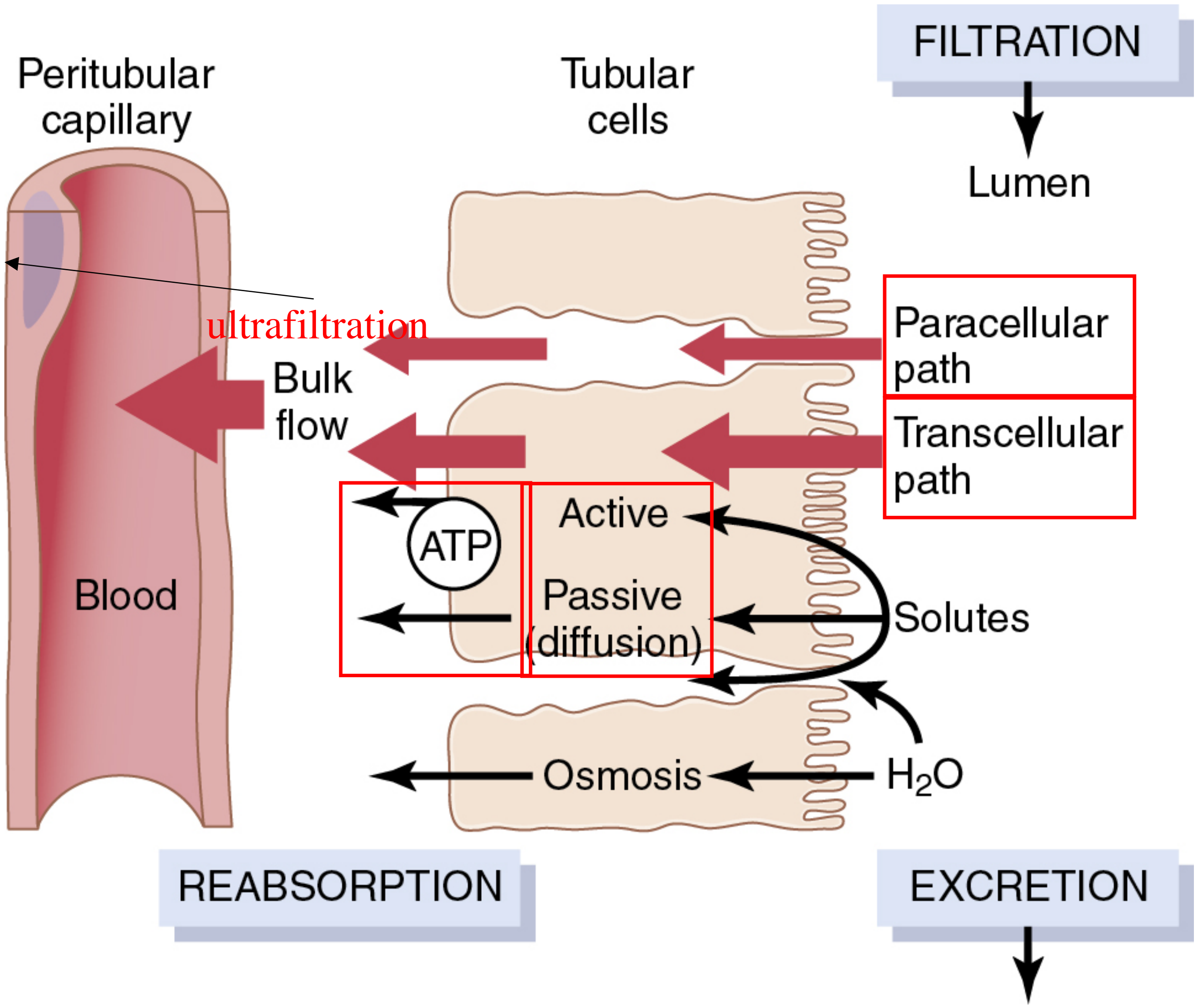
Changes in tubular reabsorption and glomerular filtration are closely coordinated to avoid large fluctuations in excretion

Tubular reabsorption

- Highly selective
- Glucose and amino acids are completely reabsorbed
- Electrolytes are mostly reabsorbed but dependent on body needs
- Urea & creatinine poor absorption
- Tubular reabsorption includes passive and active mechanisms

Reabsorption of Water and Solutes

mediated by hydrostatic and colloid osmotic forces



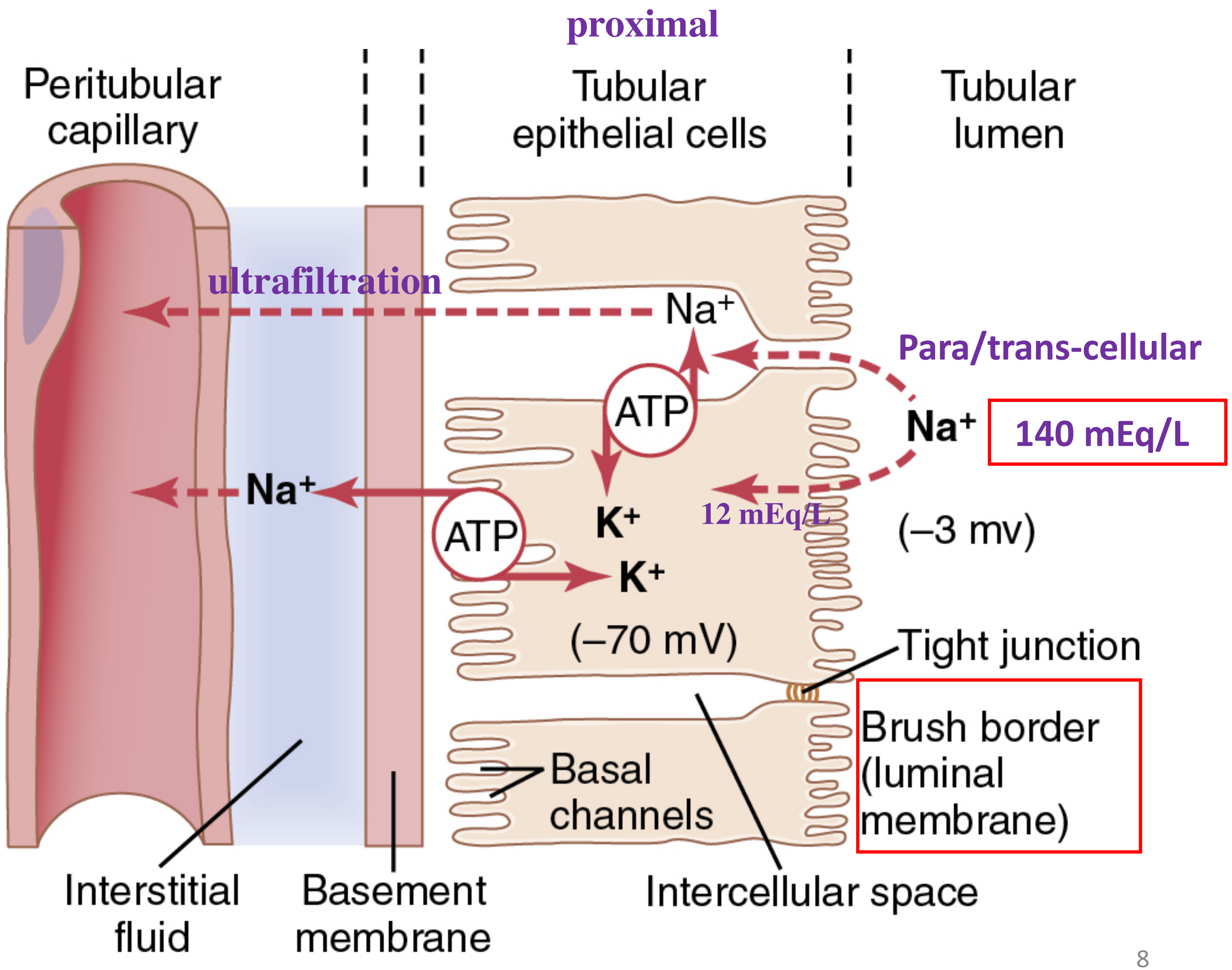
ACTIVE TRANSPORT

- Moved against electrochemical gradient
- ATP-dependent

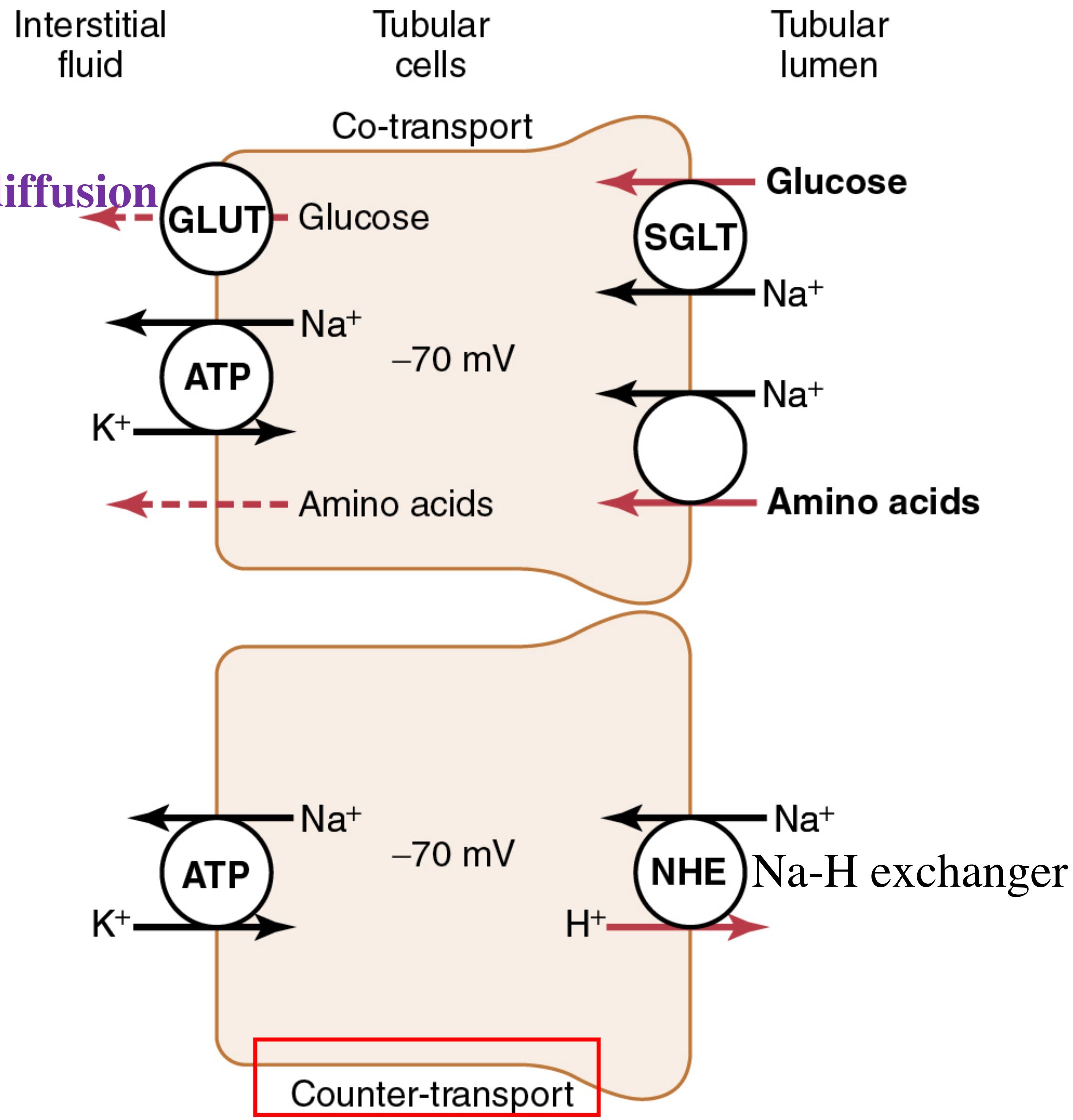
- Primary active transporters in kidneys:
- Na-K ATPase
- H-ATPase
- H-K ATPase
- Ca ATPase

Primary Active Transport of Na^+

Passive diffusion of Na (Carrier proteins)
1-concentration gradient difference
2- -70 mV intracellular potential attracts positive Na



Mechanisms of secondary active transport.



Pinocytosis

- An **Active** Transport Mechanism for Reabsorption of Proteins
- Inside the cell, protein is digested into amino acids→ reabsorbed through basolateral membrane into interstitial fluid.

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

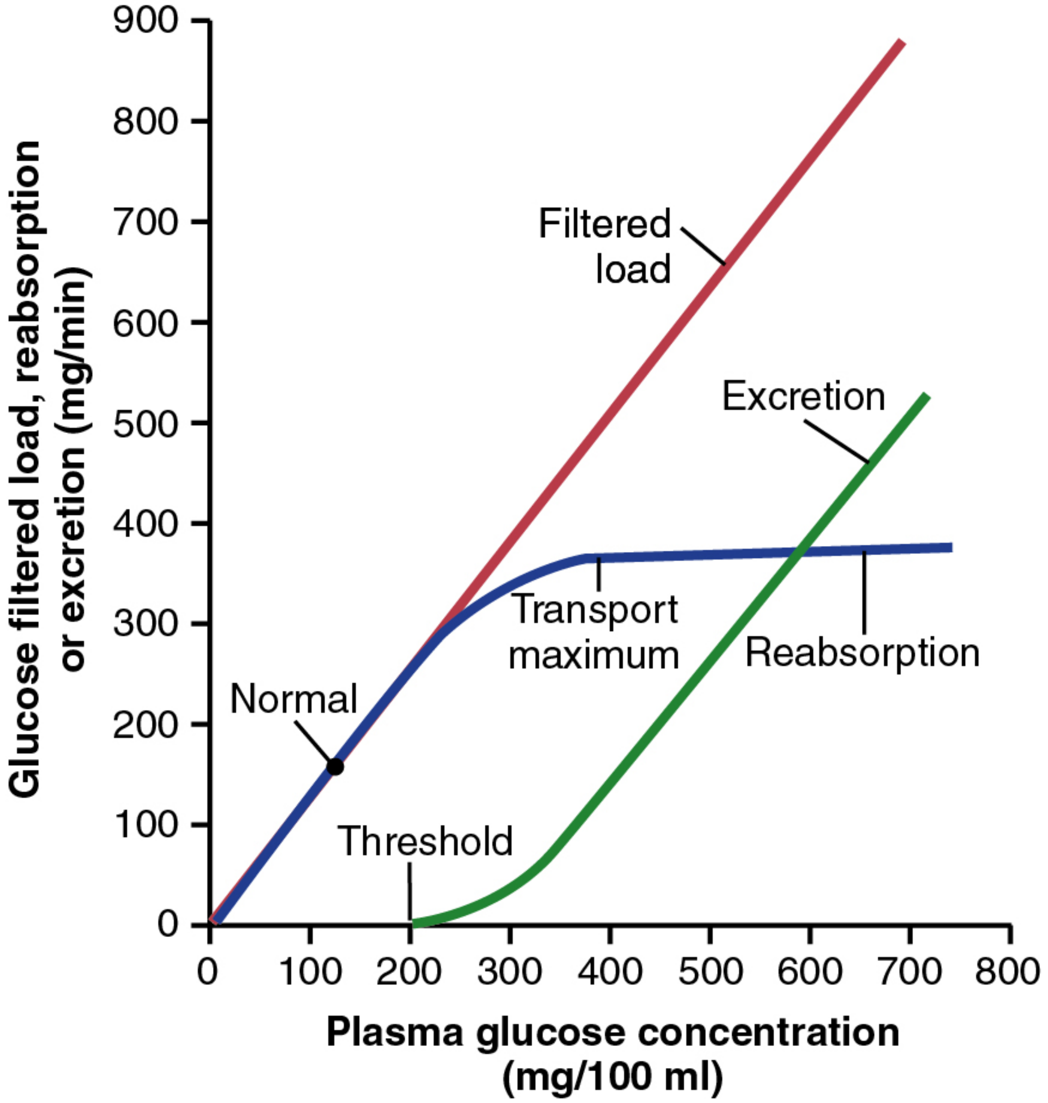
Glucose Transport Maximum

- Normally **No** glucose in the urine -all filtered
- glucose is reabsorbed in proximal tubule.

- When filtered load > Tm →urinary excretion of glucose

- Appearance of glucose in urine (at the threshold) occurs before transport maximum is reached.!! Why?
- not all nephrons have the same transport maximum for glucose→ some of nephrons begin to excrete glucose before others have reached their transport maximum.

- The overall transport maximum for the kidneys which is normally about **375 mg/min**, is reached when **all** nephrons have reached their maximal capacity to reabsorb glucose.

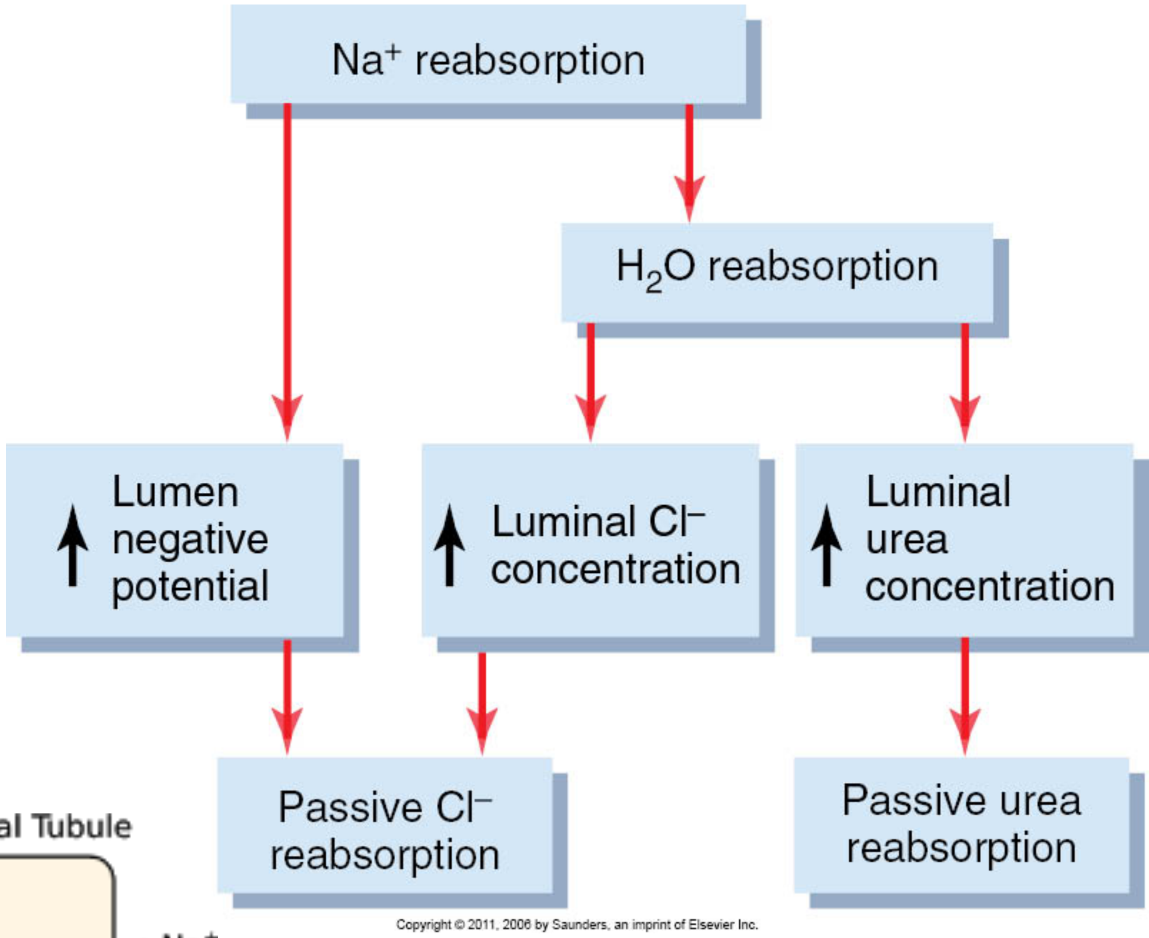


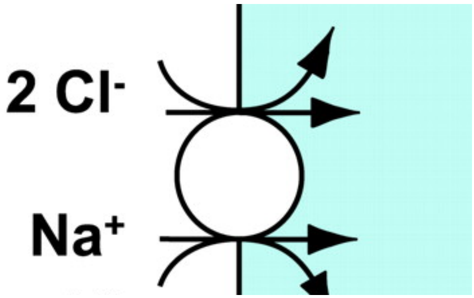
Reabsorption of Water and Solutes is Coupled to Na^+ Reabsorption

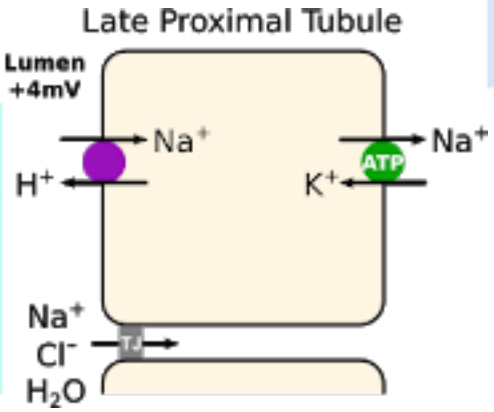
- H2O is absorbed by osmosis through tight junctions
- Proximal tubules are highly permeable to water
- H2O osmosis drag other solutes (Na, Cl, K, Ca & Mg) mainly in proximal T. Distally less permeable membrane & less surface area→ less solvent drag & osmosis

Reabsorption of Water and Solutes is Coupled to Na^+ Reabsorption

- Cl reabsorption (paracellular pathway) occurs via passive diffusion due to Na and water reabsorption
- Secondary active transport of chloride occurs a along with active transport of Na
- Urea is reabsorbed passively in the different segments of the nephron.
- Creatinine is large molecule and is essentially impermeant to the tubular membrane→almost none is reabsorbed

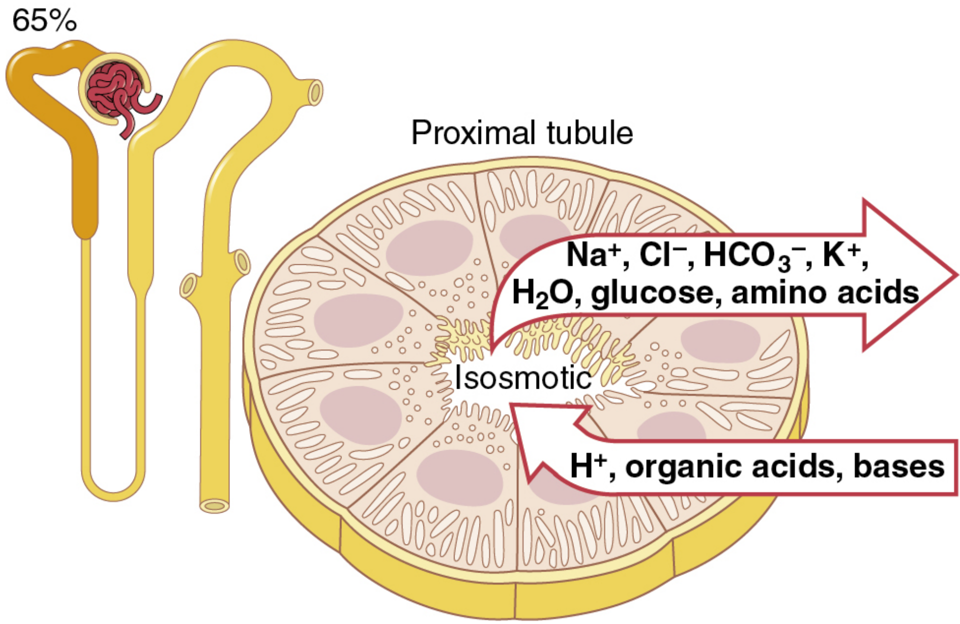






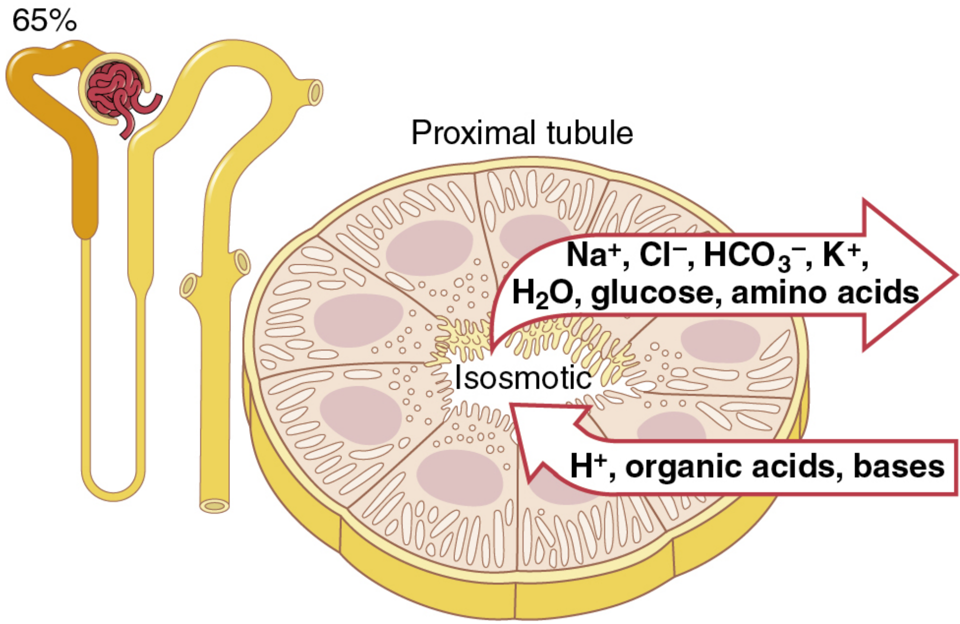
Transport Characteristics of Proximal Tubule (PT)

- Proximal tubules have a high capacity for active & passive reabsorption→↑ mitochondria & extensive brush border on luminal side, extensive basal channels →↑ SA



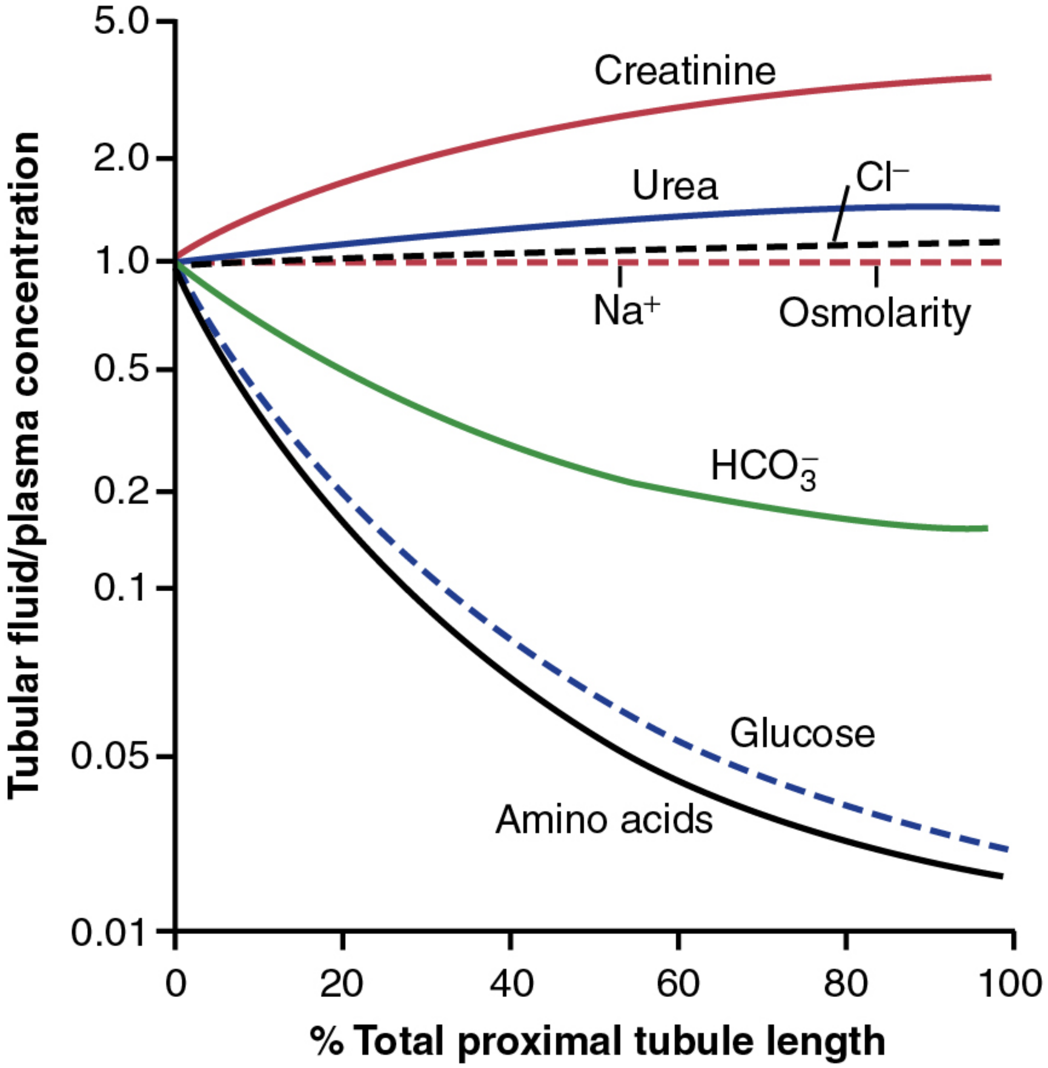
Transport Characteristics of Proximal Tubule (PT)

- PT reabsorb 65% of filtered Na, Cl, HCO3, & K
- Na is mainly reabsorbed by primary transport
- In 1st ½ of PT→ Na, GLU& AA → **COTRANSPORT**
- In 2nd ½ of PT → low GLU& AA & high Cl →mainly Cl reabsorption by diffusion through intercellular j.



- Reabsorb all filtered glucose and amino acids
- Secrete organic acids, bases, & H^+ into lumen.
- H^+ secretion binds HCO3 → H2CO3→H2O +CO2
- Secretion of drugs (penicillin and salicylates),toxins, bile salts , ureat oxlate and catcholamines are secreted by the proximal tubule.

Changes in Concentration in Proximal Tubule



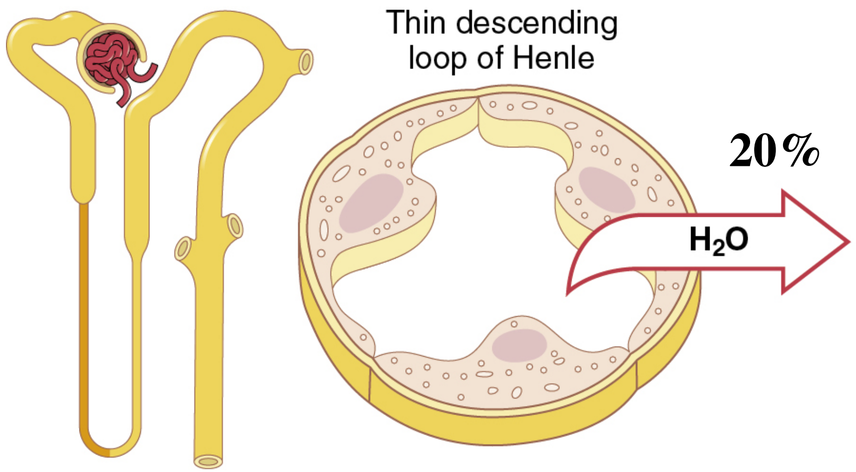
=1.0 concentration of substance in tubular fluid = concentration in plasma→High H2O permeability
<1 substance is reabsorbed> H2O
>1.0substance is reabsorbed < H2O or is secreted into the tubules.

Transport characteristics of loop of Henle

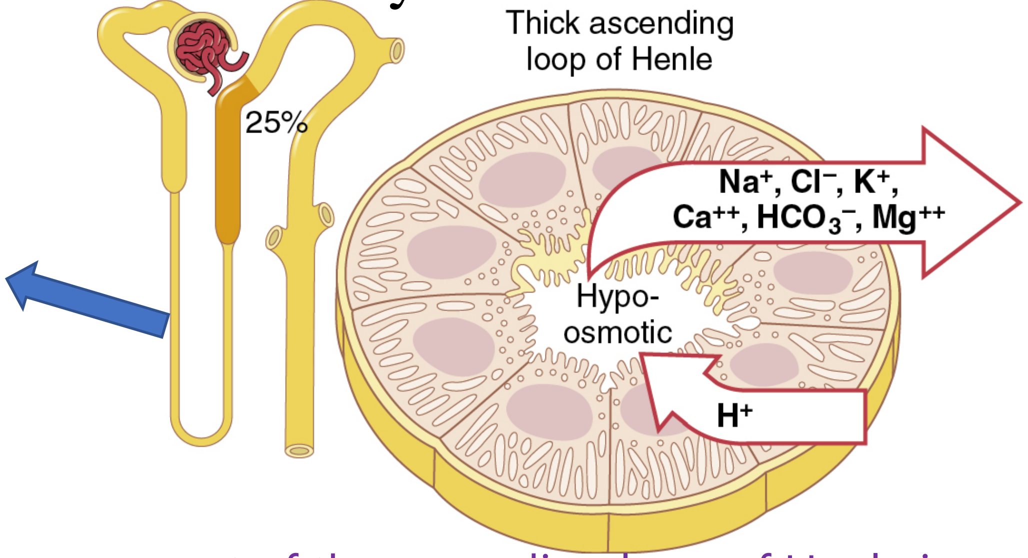
3 functionally segments:

1- thin descending
2-thin ascending
3-thick ascending

(1 and 2:)
thin epithelium
no brush borders
few mitochondria
minimal levels of metabolic activity

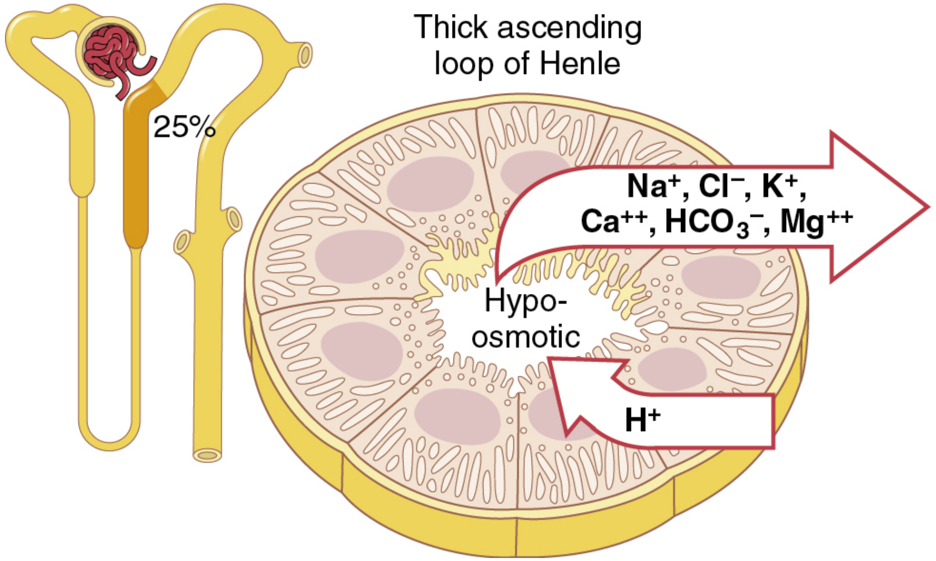


highly permeable to H2O
moderately permeable to most solutes



Ascending segment of the ascending loop of Henle is virtually **impermeable** to water

Transport characteristics of loop of Henle



~ 25% of filtered load

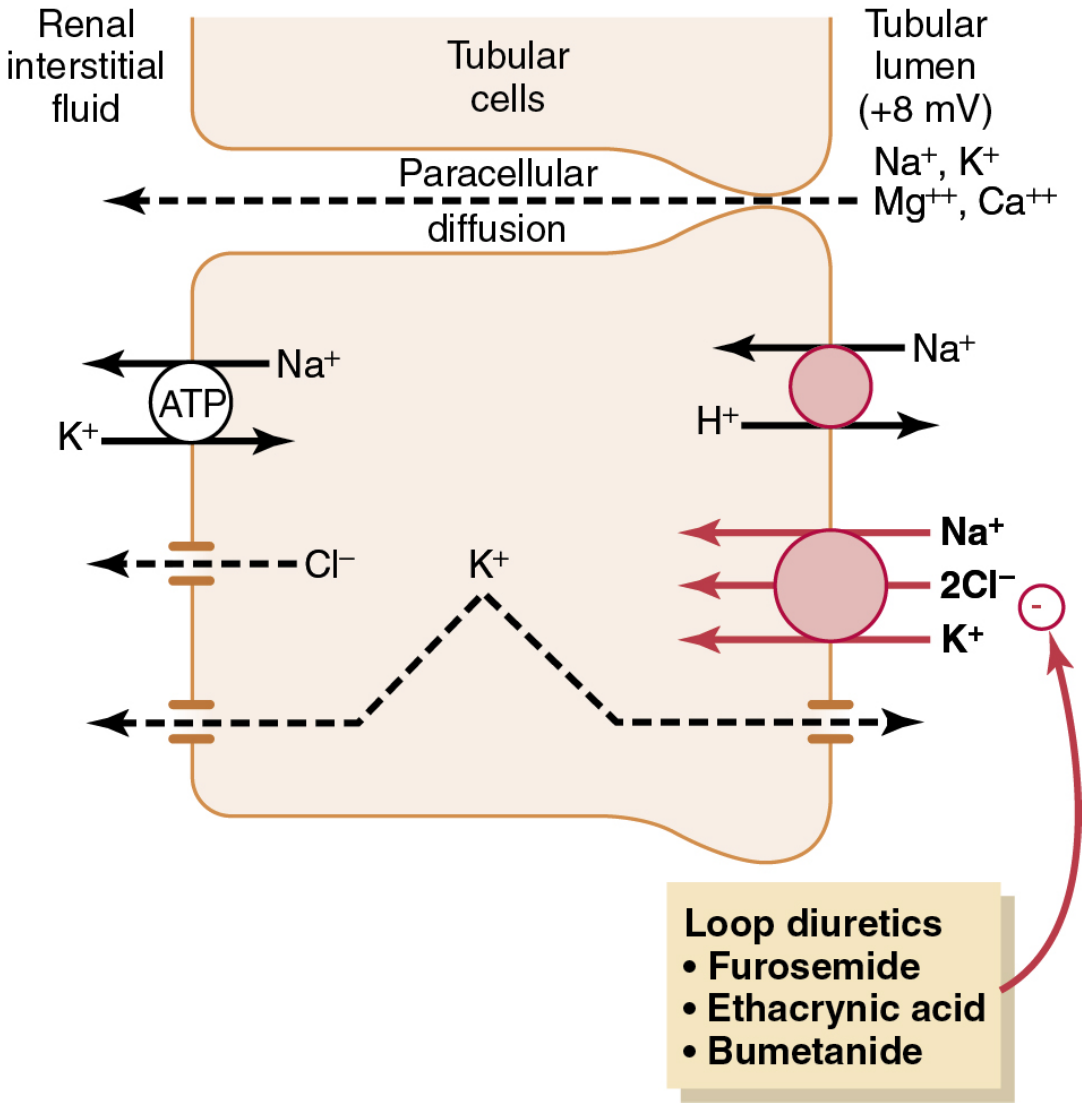
- Reabsorption of Na^+, Cl^-, K^+, HCO_3^-, Ca^{++}, Mg^{++}
- Secretion of H^+
- not permeable to H_2O

Transport characteristics of loop of Henle

- NaCl & K transport in thick
- ascending loop of Henle depends on Na+-K+ATPase
- In the epithelial cell basolateral membranes
- Pump →↓ intracellular Na→ favorable gradient for movement of Na from tubular fluid into cell.

- Movement of Na is mediated primarily by a 1-Na, 2-Cl, 1-K co-transporter

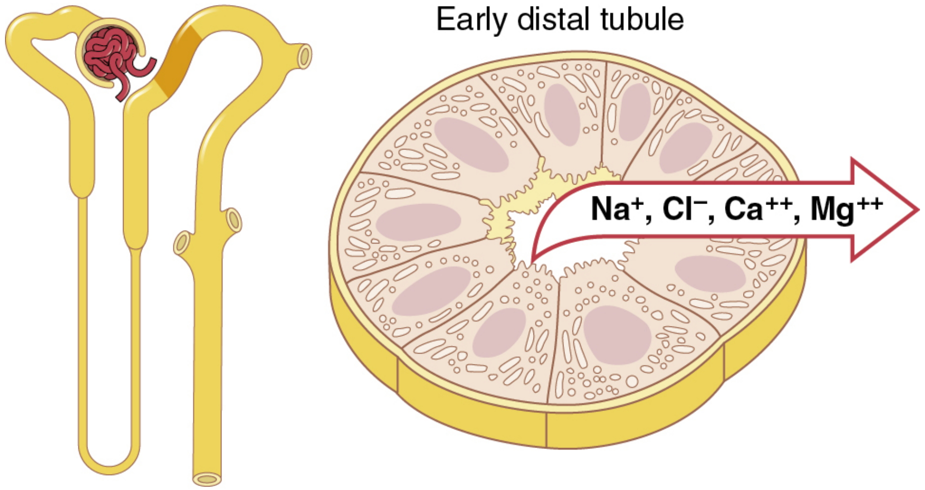
- Na-H counter-transport mechanism



Early Distal Tubule

- Functionally similar to thick ascending loop
- Not permeable to water (called diluting segment)
- Active reabsorption of Na^+, Cl^-, K^+, Mg^{++}
- Early part contains macula densa (part of juxtaglomerular complex)& provides feedback control of GFR and RBF.
- The next part of the distal tubule is highly convoluted →reabsorbs most of ions& impermeable to water and urea.

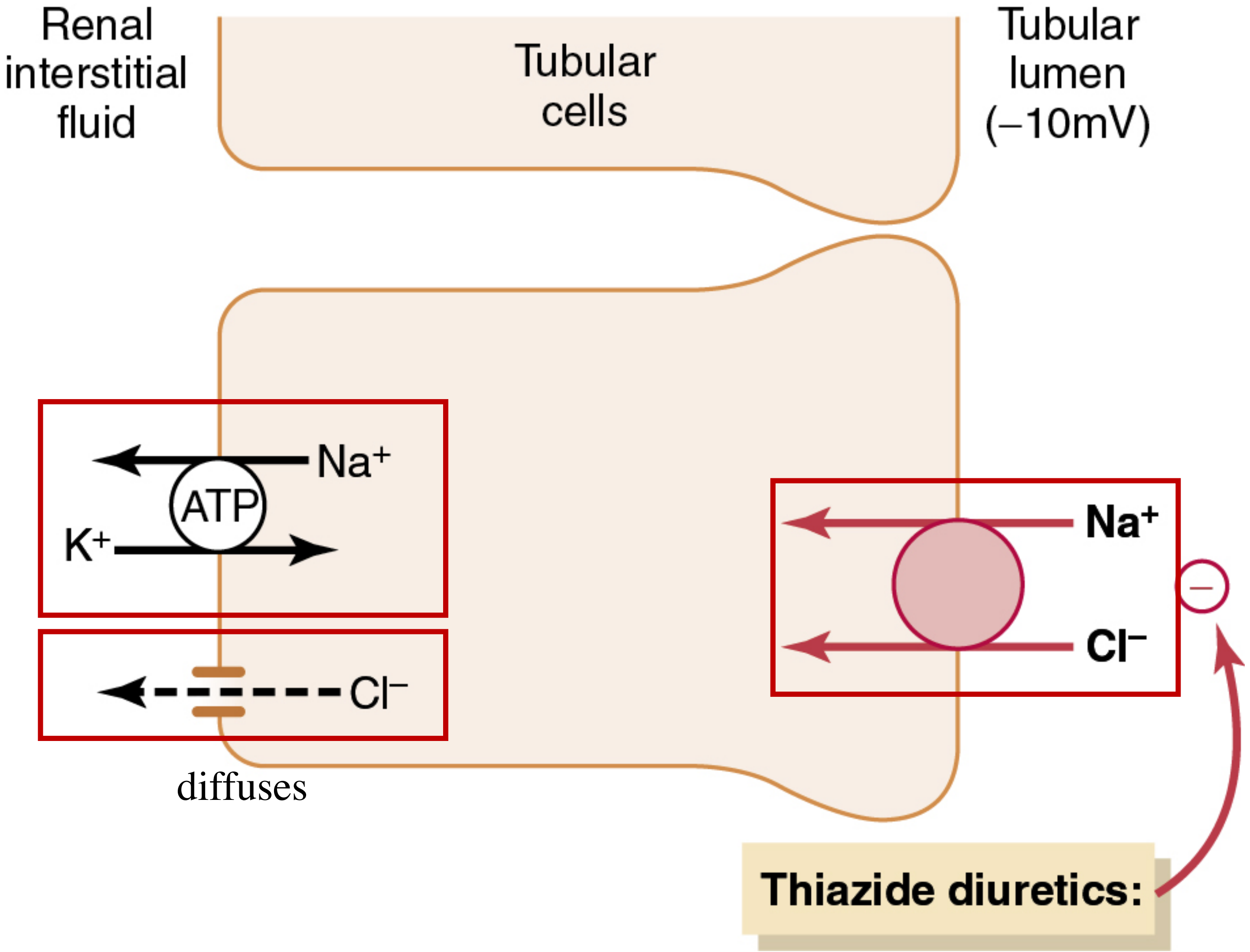
Early Distal Tubules



~ 5% of filtered load NaCl reabsorbed

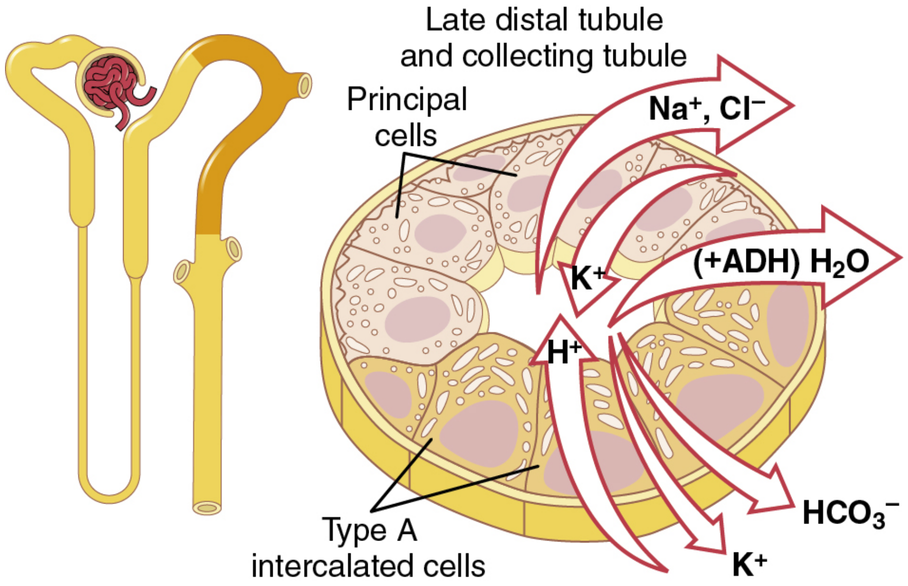
- <u>not</u> permeable to H_2O
- not very permeable to urea

Early Distal Tubule



Late Distal Tubules and Collecting Tubules.

Late Distal Tubules and Collecting Tubules have similar functional characteristics



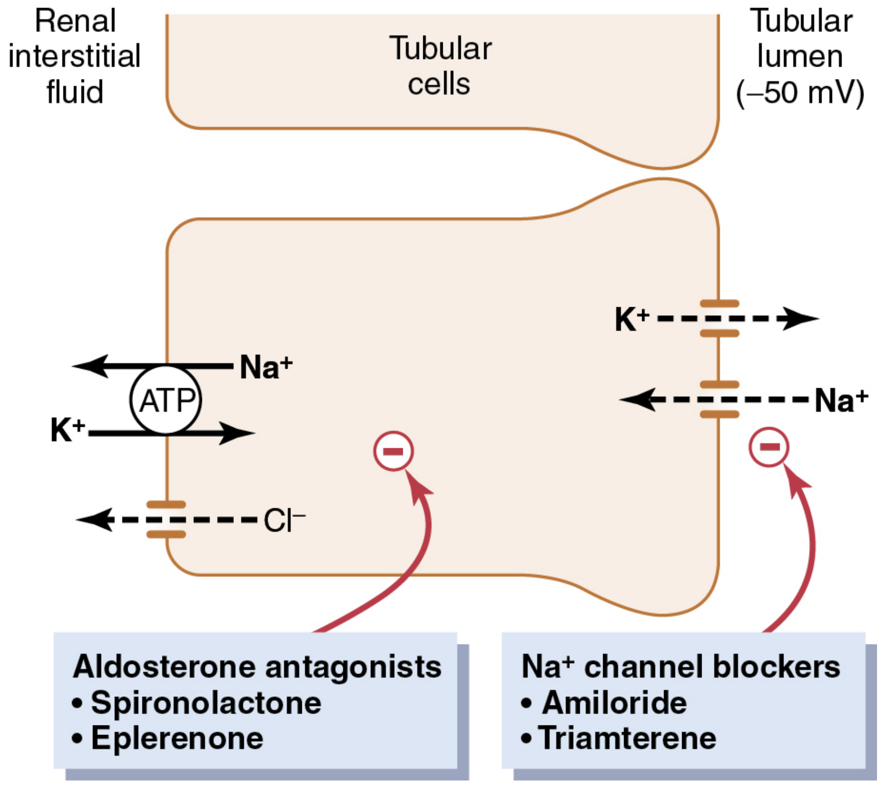
- permeablility to H_2O depends on ADH
- not very permeable to urea

Principal Cells Reabsorb Na and Secrete K

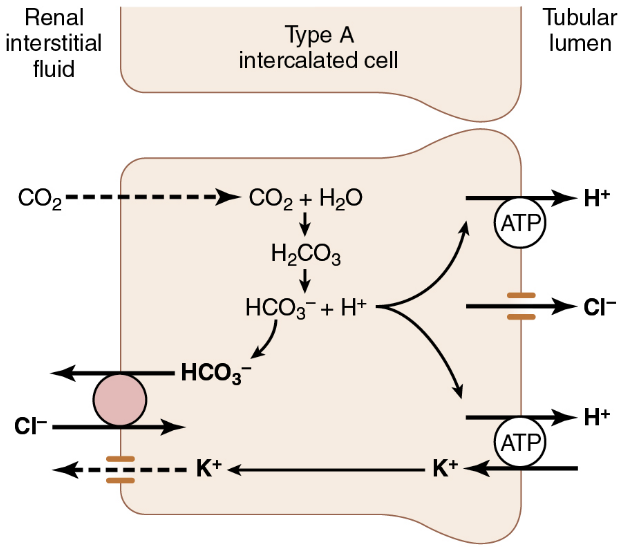
- Depend on activity of Na+-K+ATPase pump basolateral membrane. Low intracellular Na→Na diffusion in+ high intracellular K →K diffusion OUT

- The principal cells are the primary sites of action of the K-sparing diuretics.
- Aldosterone antagonists inhibit stimulatory effects of aldosterone on Na reabsorption and K secretion.

- Na channel blockers inhibit the entry of Na into Na channels of →↓ Na that can be transported across the basolateral membranes by the Na+-K+ATPase pump.

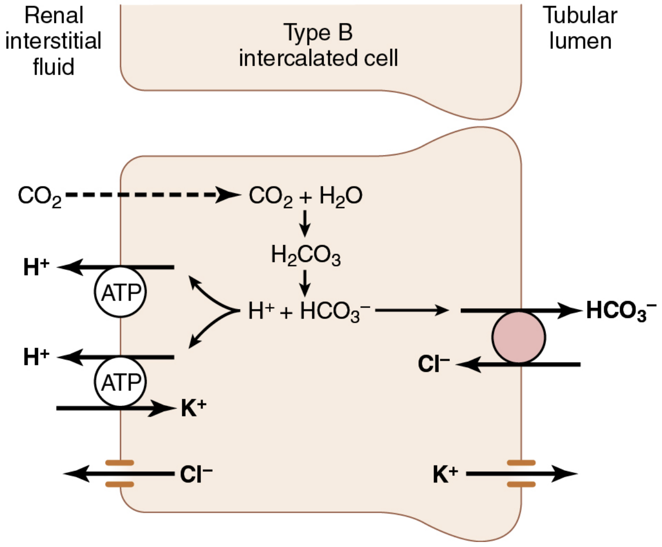


Intercalated Cells Secrete H and Reabsorb HCO3 & K



Type A intercalated cells

- H secretion is mediated by a H-ATPase
- H is generated in this cell by the action of CA on H2O and CO2 to form H2CO3→dissociates into H & HCO3.
- H secreted into the tubular lumen, and for each H secreted, HCO3 becomes available for reabsorption across the basolateral membrane.



Type B intercalated cells

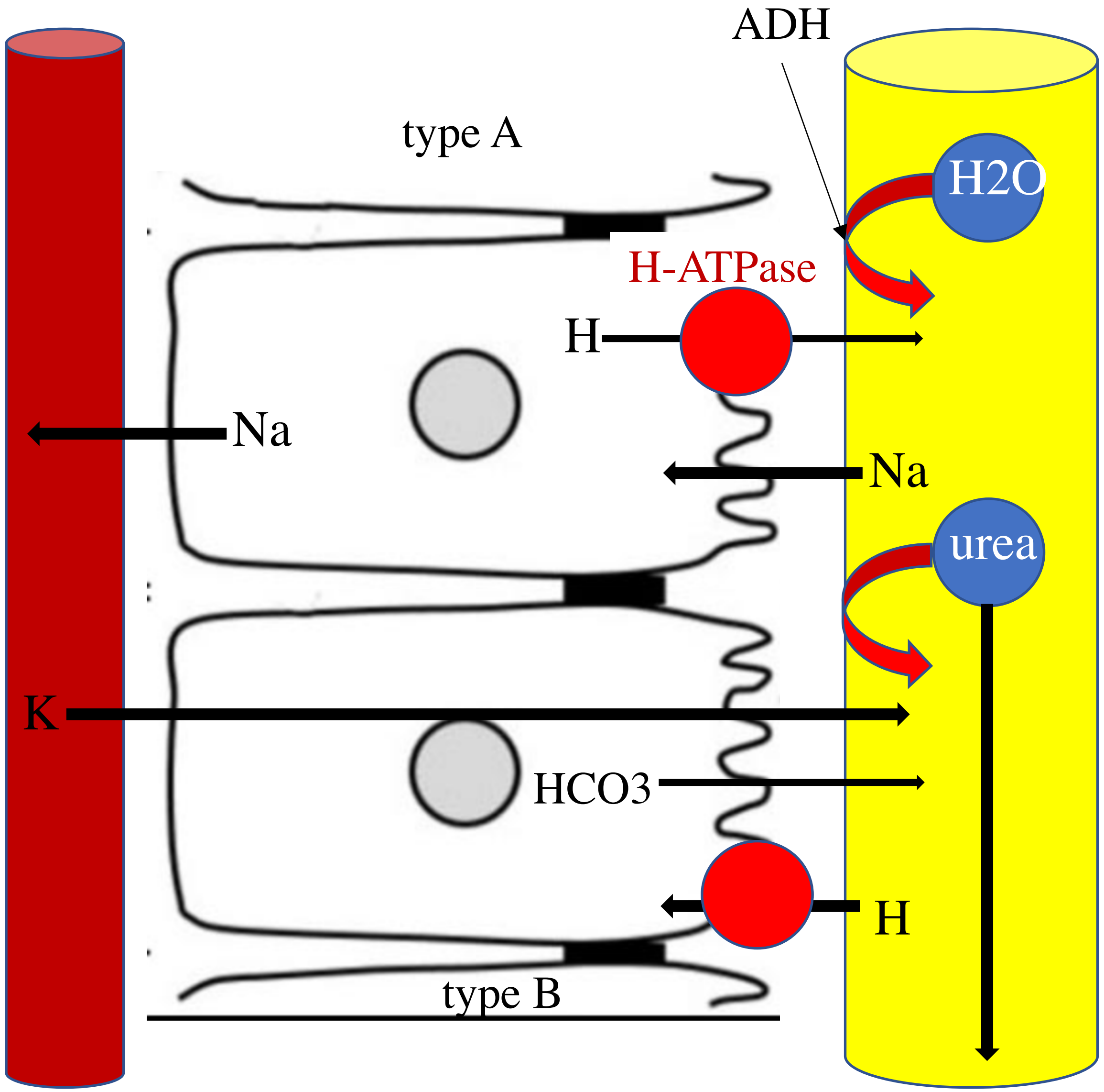
- Functions is opposite to those of type A cells (in alkalosis)
- HCO3 to lumen
- H reabsorption via H-ATPase

Intercalated cells can also reabsorb or secrete K

Late distal tubule & cortical collecting tubule

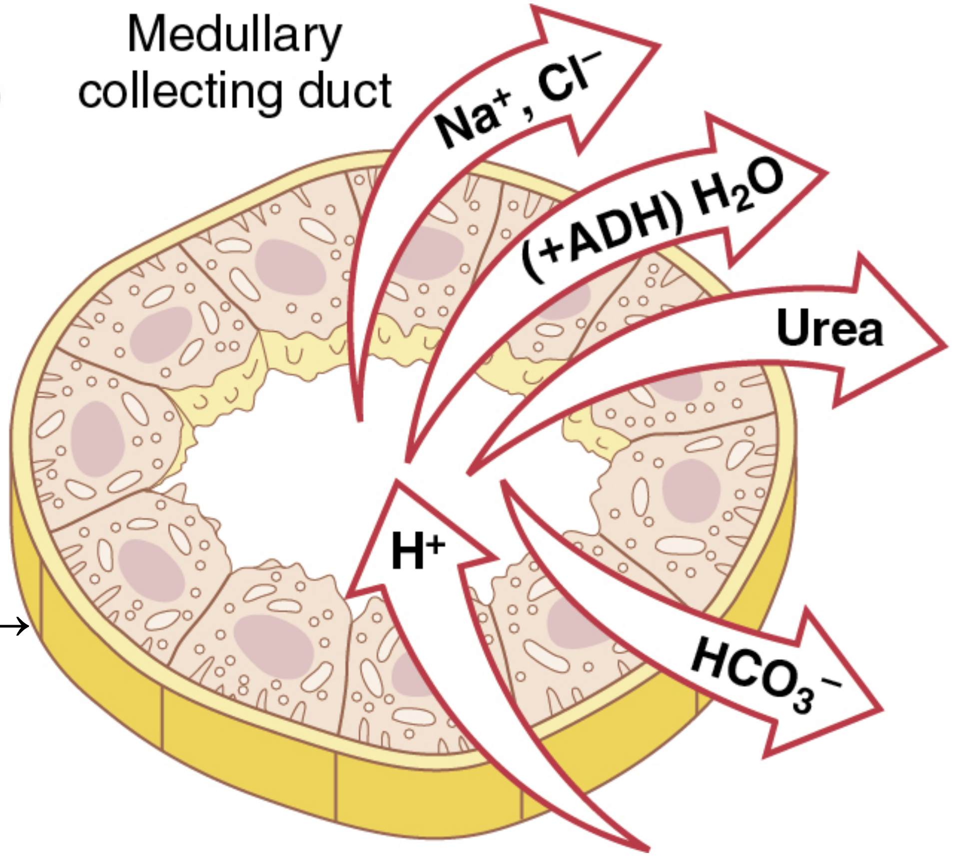
<u>Functional characteristics:</u>

1. impermeable to urea, some reabsorption of urea occurs in the **medullary** collecting ducts.
2. reabsorb Na→ controlled by hormones, especially aldosterone.
3. secrete K from peritubular capillary to lumen controlled by **aldosterone**
4. play a key role in acid-base regulation
-type A intercalated cells → secrete H by active H-ATPase mechanism in **acidosis**.
-type B intercalated cells secrete HCO3 and actively reabsorb H In **alkalosis**
5. controlling the degree of dilution or concentration of the urine →permeability to water is controlled by concentration of ADH/vasopressin.
↑ ADH → ↑ permeability
↓ADH → ↓ permeability



Transport characteristics of medullary collecting ducts

- Reabsorb <10% of filtered H2O & Na.
- The final site for processing the urine.
- Play an extremely important role in determining the final urine output of water and solutes.
- Its permeability to water is controlled by the level of ADH.
- permeable to urea→urea is reabsorbed into medullary interstitium → helping to raise the **osmolality** in this region of the kidneys and contributing to the kidneys' overall ability to form a **concentrated** urine.
- Secretes H against a large concentration gradient→ plays a key role in regulating acid-base balance.



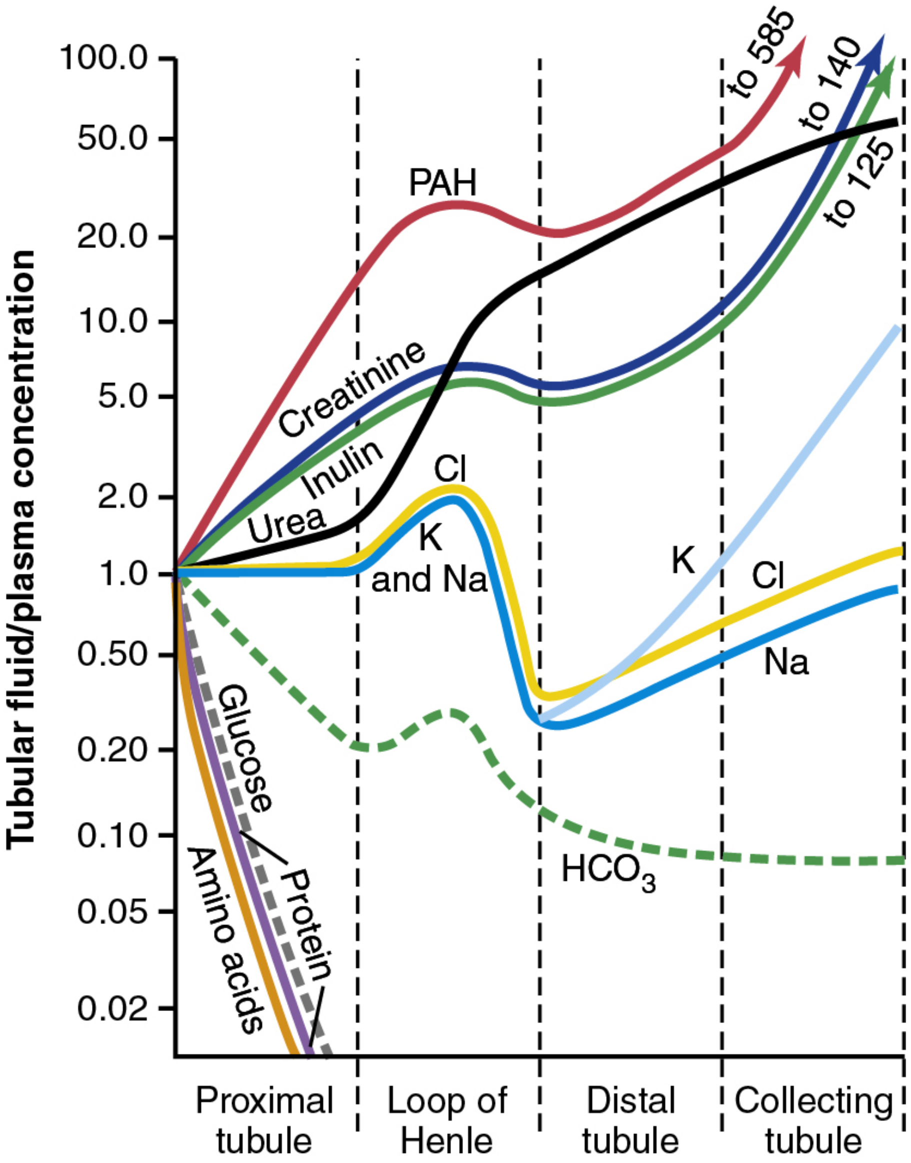
concentrations of substances in the renal tubules

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

- 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



more water is reabsorbed than solute

more solute is reabsorbed than water

The End