النادي الطلابي
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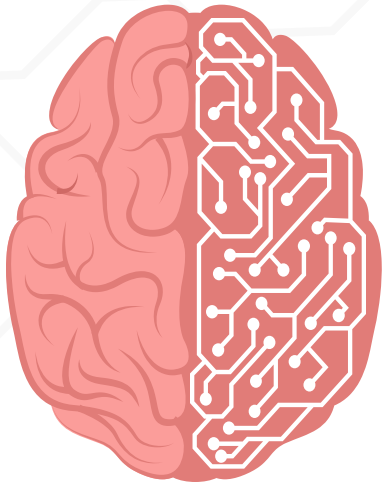

Physiology - GUS

Done By

Heba Al Tahat, Raneem Al Zoubi

Corrected By

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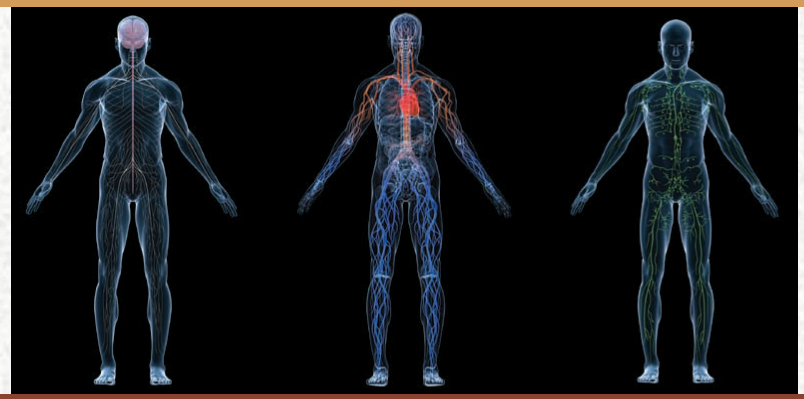
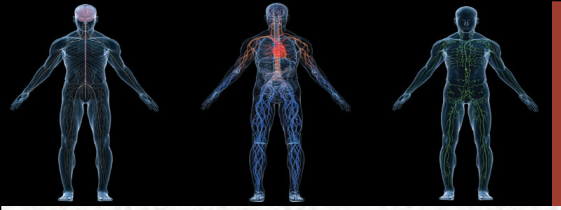
UNIT V

GUYTON AND HALL *Textbook of*
Medical Physiology
TWELFTH EDITION



Chapter 27:

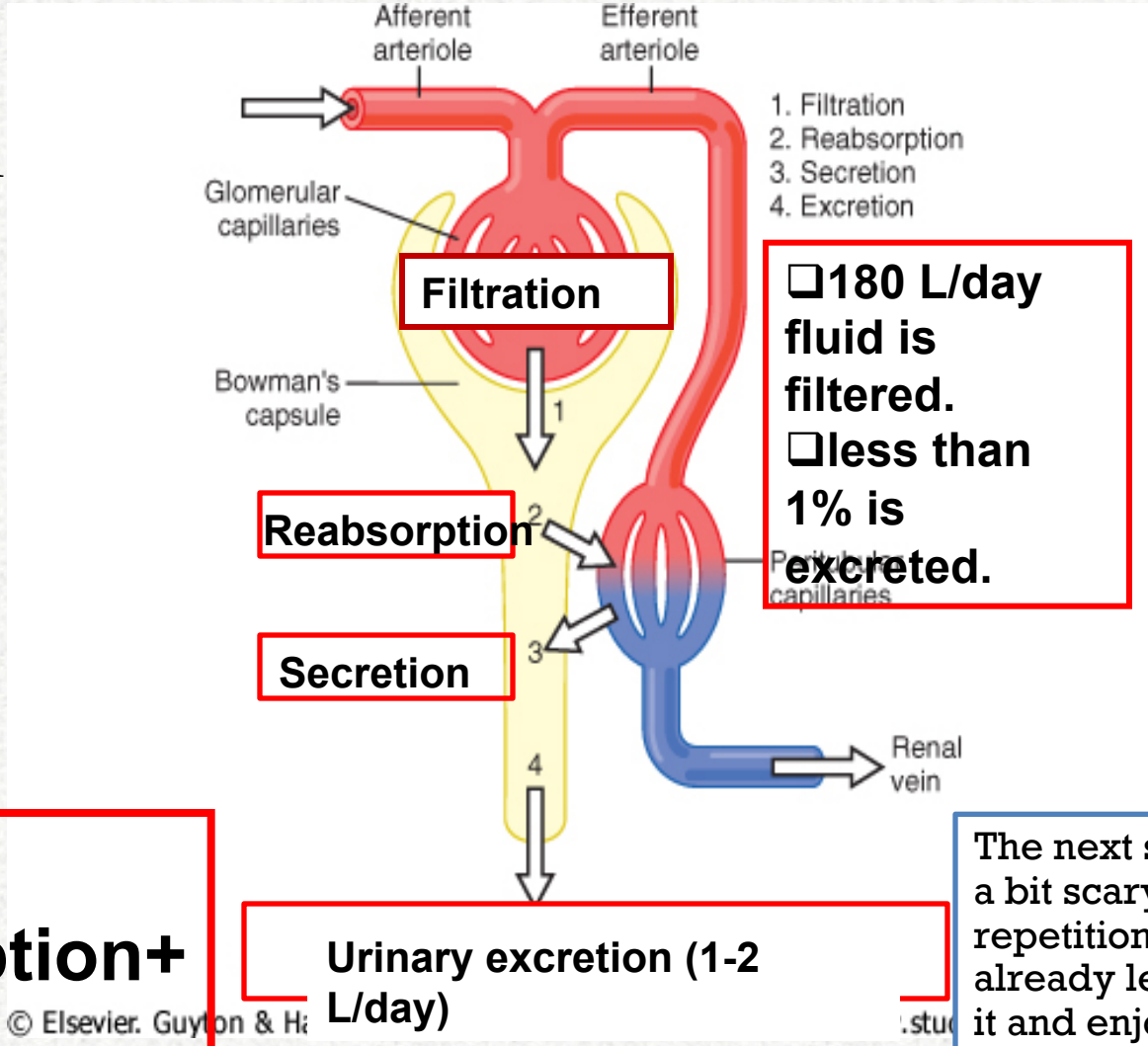
Urine Formation by the Kidneys:
II. Tubular Reabsorption and Secretion



The functional unit of the kidney

Basic Mechanisms of Urine Formation

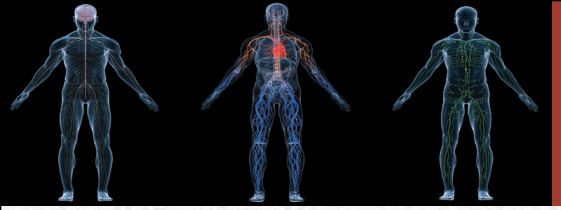
- Ultra filtration
- Reabsorption
- Secretion
- Excretion



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

Excretion= Filtration-Reabsorption+ Secretion

The next slide might look a bit scary but it is all repetition to things we already learnt. Just read it and enjoy



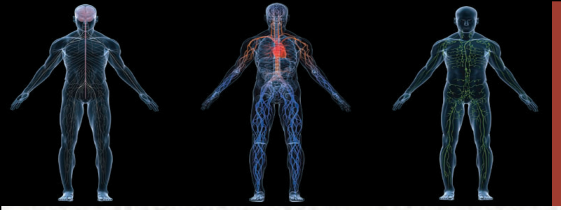
- These mechanisms occur in the nephron which is a micro-structure in the kidney and its blood supply is through an afferent arteriole. The arteriole has smooth muscle cells, Then we have a capillary system called the glomerulus and it consists of only one layer of epithelial cells, and this is because its function is the occurrence of filtration across its membrane, these epithelial cells have high fenestrations, and this makes filtration more effective.

- The fluid that is filtered goes through Bowman's capsule after crossing the interstitial space, Bowman's capsule is a sac-like structure that the surrounds the glomerulus, like a balloon, so the glomerulus is denting its surface. After passing through Bowman's capsule, it travels through a tubular system. Then this fluid will pass through the rnal papilla into the renal calyces and finally into the renal pelvis.

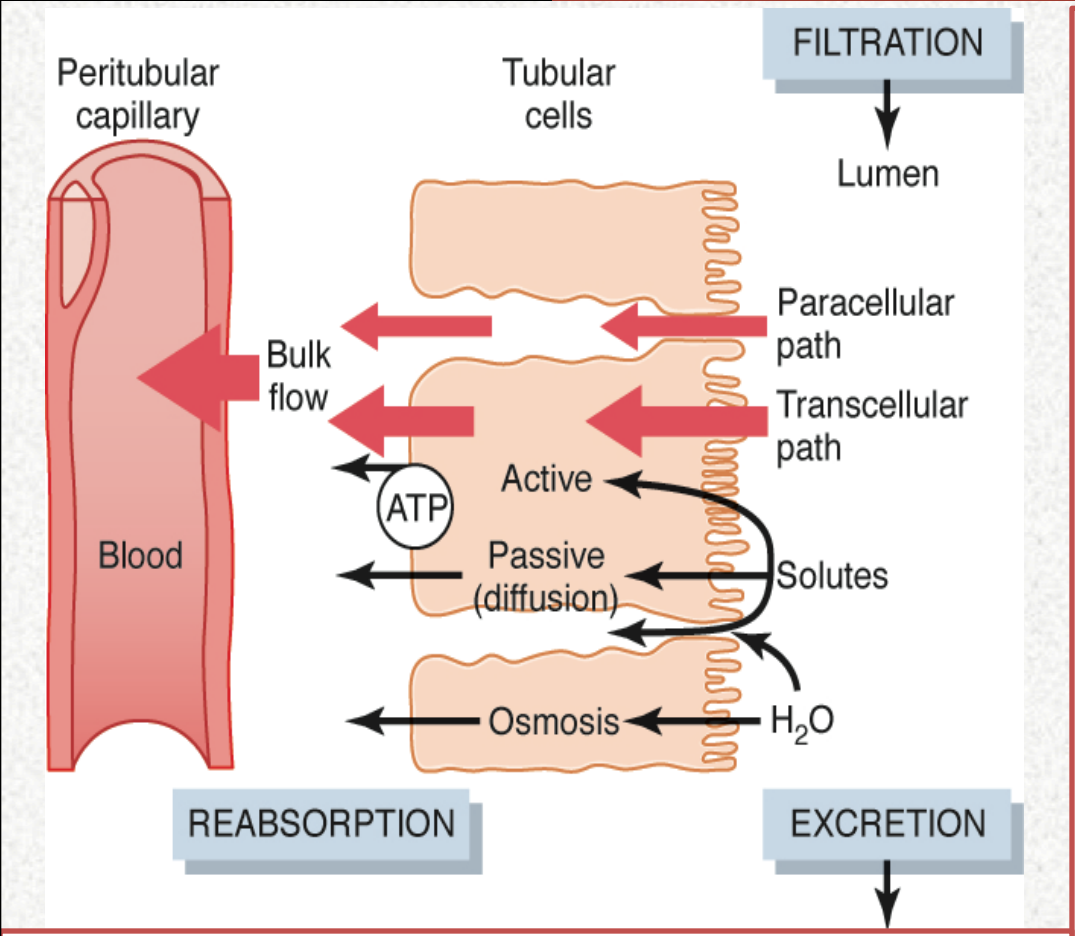
- This lecture is about reabsorption, and in contrary to filtration, it is highly selective, and that means that the reabsorption rate differs based on the type of the substance.
  Valuable substances that the body needs will be reabsorbed almost completely (high reabsorption rate) but the wastes in our body such as creatinine and urea have a low reabsorption rate so that they can be excreted from the body.

- Secretion is different than excretion. Secretion is an active process to eliminate substances that are toxic (wastes). To remove them from the blood (the peritubular capillaries) to the filtered fluid and finally to the urine and it is in a higher rate than the filtration.
- So, we don't always depend on the amount of a certain substance filtered through the glomeruli, but we also secrete even more than what was filtered to be excreted.

- The 180L filtered each day are the same 5L of our blood but they get filtered (screened) through the kidneys 60 times a day, any wastes are gotten rid of, and any imbalance is detected and corrected.



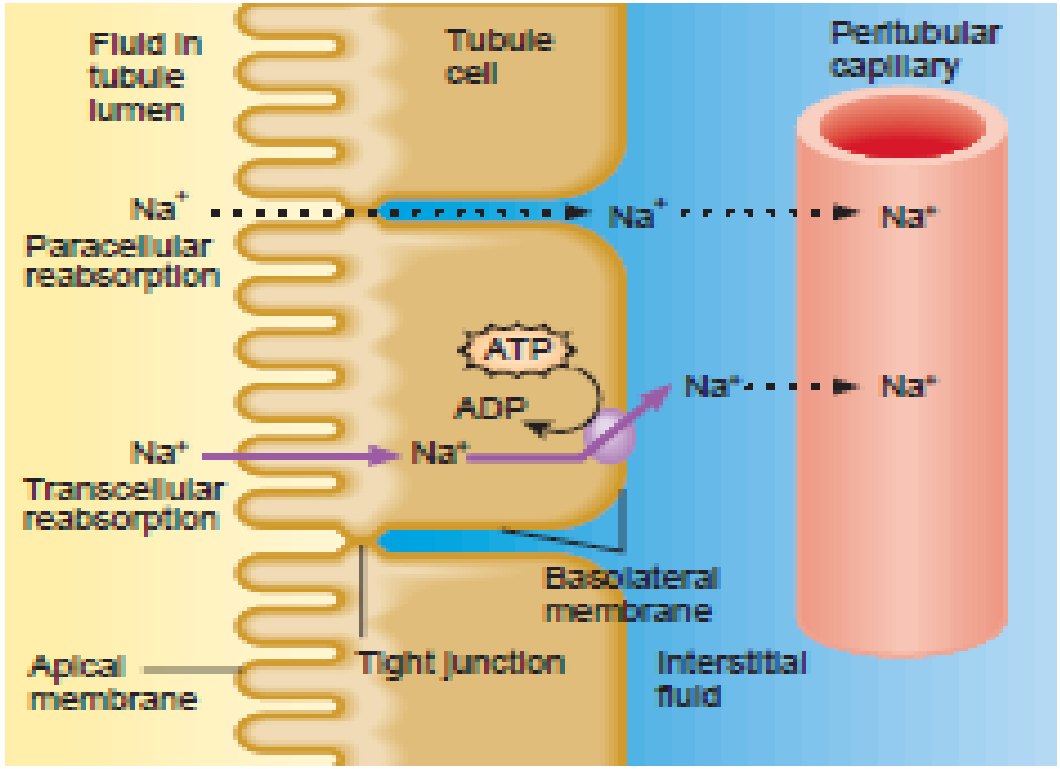
Reabsorption of Water and Solutes



- The wall of the proximal convoluted tubules is a single layer of epithelial cells, they have basal side which faces the capillaries and an apical side which faces the tubular fluid and the lumen of the tubule.

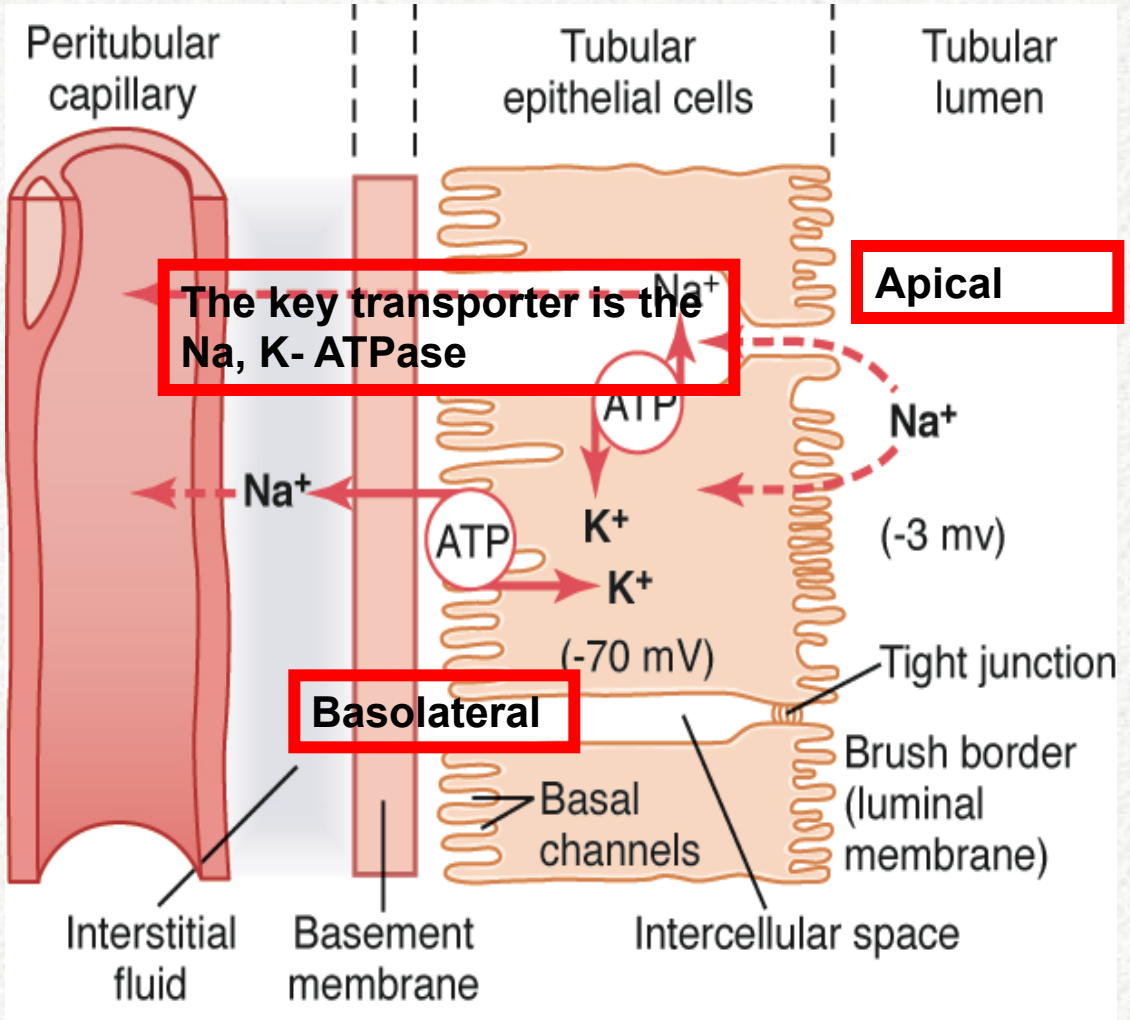
- Now the reabsorption is through from the lumen to the capillaries; this is done by two ways either across the plasma membrane, through the epithelial cells OR inside the cells.
  There is a space called the intra cellular space between the cells, there is sometimes a kind of gap in between the tight junctions between these epithelial cells and it lets fluid to pass through, this is a route for reabsorption which is called the paracellular route.
  The other route is transcellular, which occurs through the plasma membrane of epithelial cells.
  The route chosen depends on the substance that is being transported. For example, water can only be transported with aquaporin channels and so it must take the transcellular route and so do ions.
  This transport can be either passive or active and this depends on the gradient, if the transport is down hill it will be passive transport and if it is against the gradient we will need energy and the transport will be active.
- Water is transported by osmosis, and osmosis is the movement of water from the lower osmolality to the higher osmolality, it is a passive process.
  Whatever substance that is not reabsorbed from the tubules will be excreted through the urine outside the body

Reabsorption of Water and Solutes



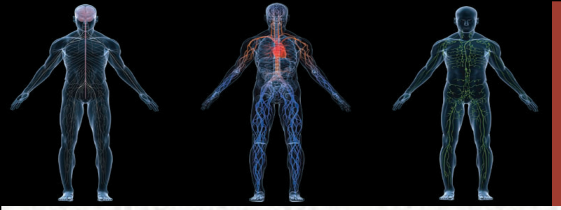
- Sodium is the main ion in the ECF or in the plasma.
- It can be absorbed either transcellularly or paracellularly.
  The transcellular route is done by the Na+-K+ ATPase pump, this pump pumps the sodium outside the cell even if it was against its gradient by consuming energy, and pumping potassium inside the cell, so it makes up a gradient for sodium for its passive transport from the tubular fluid inside the cell, and then from the cell into the interstitial fluid and then into the peritubular capillaries.
- SO the cause of the driving force for the reabsorption of sodium is the Na+-K+ ATPase pump, and this is an active process since we consume energy.
- Sodium is also transported via the paracellular route, sodium has ion channels in the lateral surface.

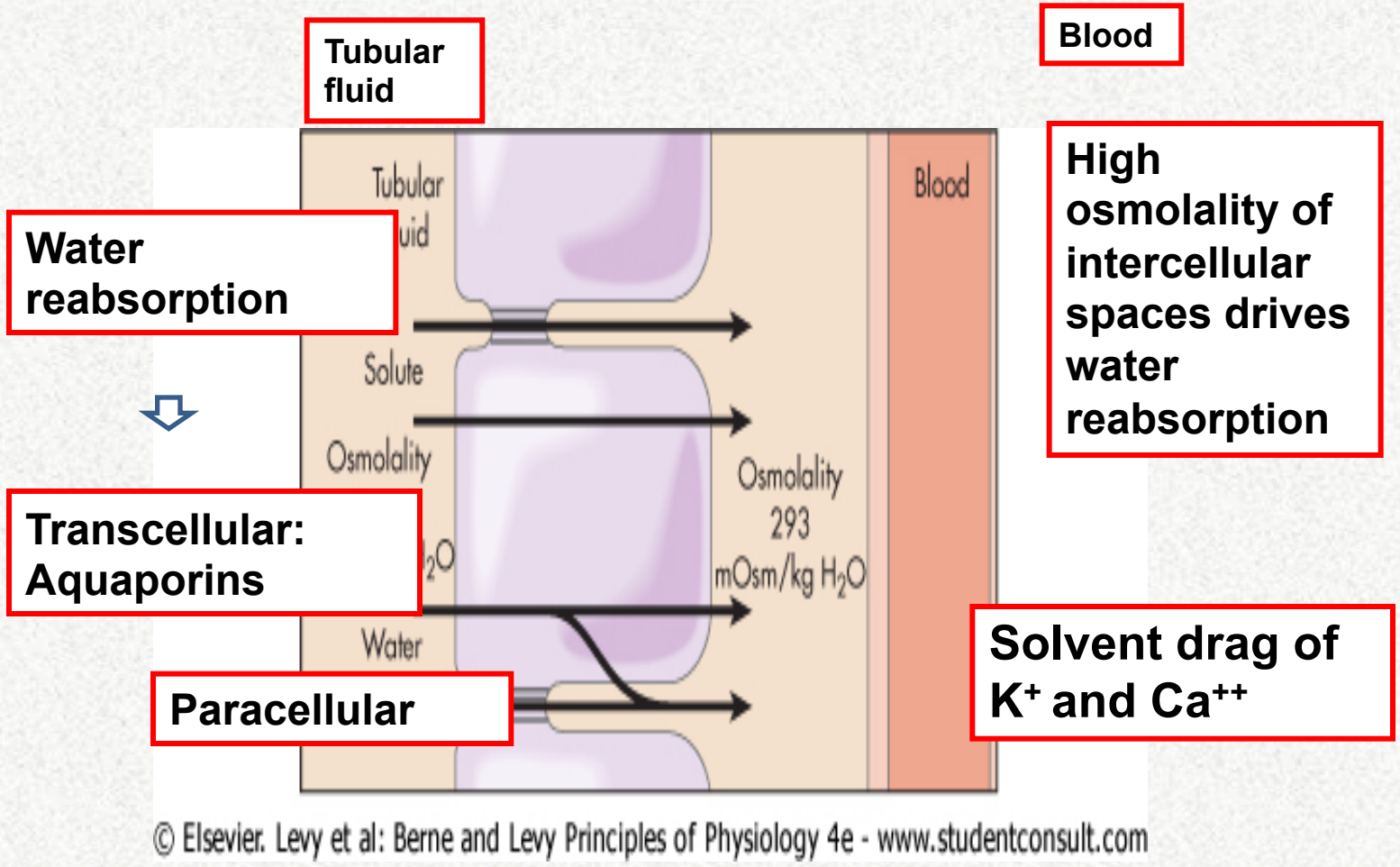
Active Transport



- The apical surface in the proximal convoluted tubule has a brush border and this increases the surface area and increases the effectiveness of reabsorption.
- The Na+-K+ ATPase pump is located on the basal and the lateral membrane (basolateral).
- Another factor (other than the chemical gradient) that favors the reabsorption of sodium is the electrical gradient, because when the sodium taken out of the cell is more than the potassium taken in, then there will be a negative membrane potential which facilitates the reabsorption of positive sodium ions.

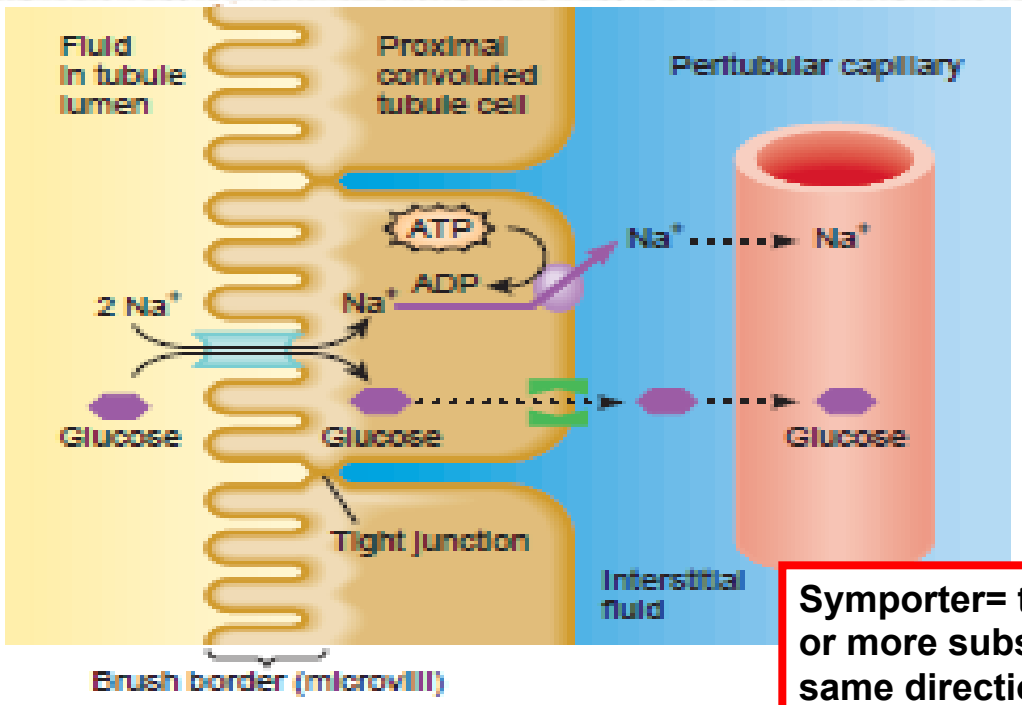
Proximal tubule reabsorption

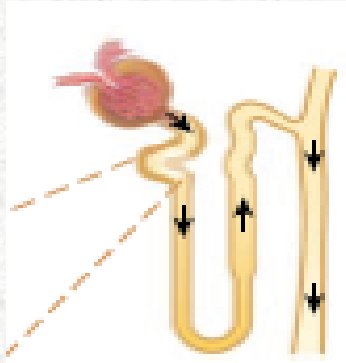




- When we transported sodium from the tubules into the blood, we increased the osmolality, this increases the driving force of water to be reabsorbed by osmosis. This reabsorption of water is present in the proximal convoluted tubules, it is possible because of the presence of aquaporin channels so water can be transported from the tubular fluid and back to the capillaries, in the two routes; paracellular and transcellular.
- Moreover, something called the solvent drag occurs, through the paracellular route, the water that is reabsorbed contains solvents that are dissolved in it, such as K+ and Ca+, which are reabsorbed with the water.
- The difference in osmolarity is made by the Na+K+ ATPase pump, but the osmosis is a passive process.

Glucose: Proximal Tubules





Symporter= transports two or more substances in the same direction

Glucose is transported via secondary active transport (facilitated diffusion)

- Substances such as glucose and amino acids are filtered through the glomerulus based on their size and charge but they are necessary for the body and it spent energy to get them, so they must be reabsorbed again.
- In the proximal convoluted tubule, glucose and amino acids are excessively reabsorbed, to the point that at the end of the tubule, almost all of them are back in the circulation.
- The channels that transport them are highly selective, and they use the gradient of sodium t transport glucose against its gradient, because we need all of the glucose not just until it reaches equilibrium.
- This process is called secondary active transport (because the sodium gradient used in transport was created by the Na+-K+ ATPase pump which used ATP) and the channels are called co-transporters or symporters.
  The glucose then is transported by facilitated diffusion back into the blood.

Mechanisms of secondary active transport.

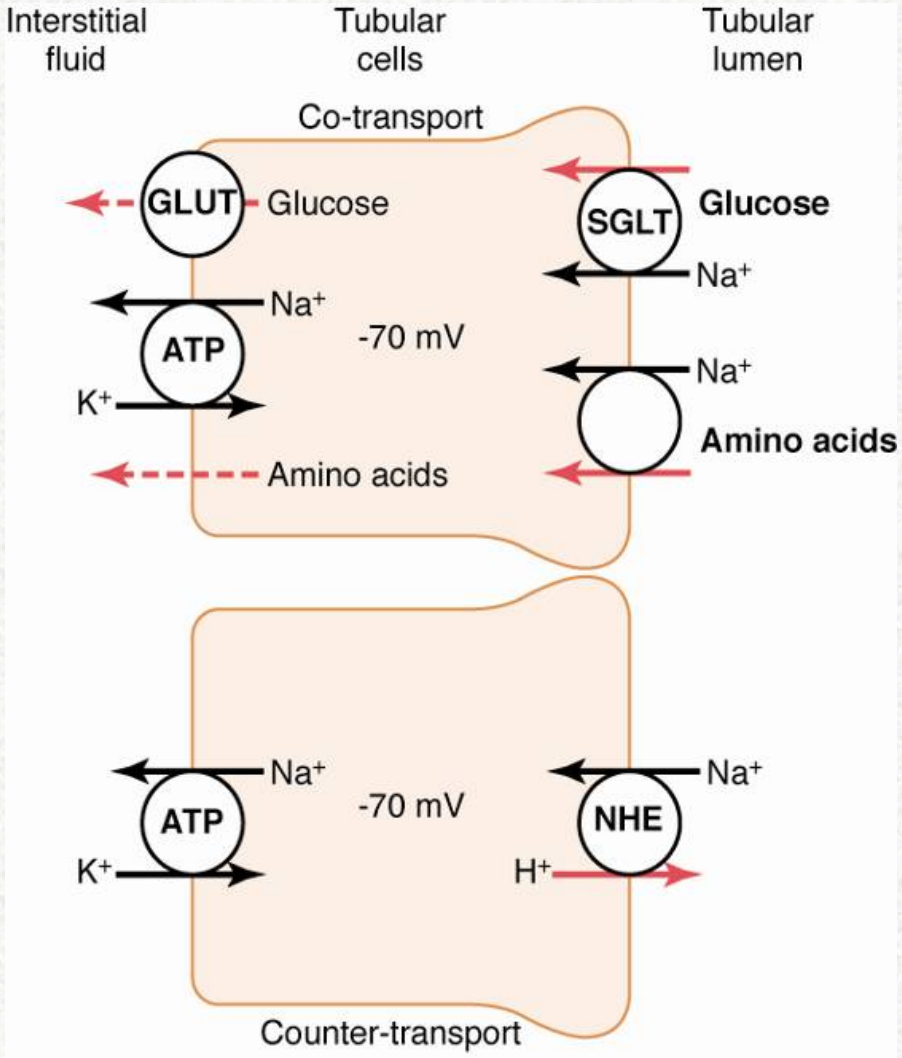
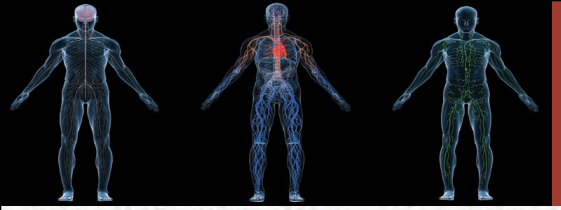


Figure 27-3

- There is co-transport and counter-transport.
- Co-transport is used in the reabsorption of glucose and amino acids.
- Counter-transport uses sodium to transport an ion in the opposite direction of sodium. An example of this channel is the Na+-H+ channel. With this channel we use the transport of sodium down its gradient to transport hydrogen ions against its gradient and into the tubular fluids. Here hydrogen is secreted not reabsorbed, because it was transported OUT of the blood and into the tubular fluid



Glucose Transport Maximum

- All filtered glucose should be reabsorbed [but this is true within a limit]
- Plasma glucose and glucose filtration should be within limits in order for glucose to be completely reabsorbed
- So if the glucose filtration was higher than the body's ability to reabsorb glucose (meaning it's higher than the transport maximum) then the glucose won't be completely reabsorbed and there'll be extra glucose in the urine excretion because the filtered glucose saturated all the transporters (so it depends on the availability of the transporter)
- Any glucose filtered more than its transport maximum is going to be excreted

- Any substance that needs a transporter has a "transport maximum" and it depends on the availability of the transporter (unlike plasma membrane diffusion which is unlimited)

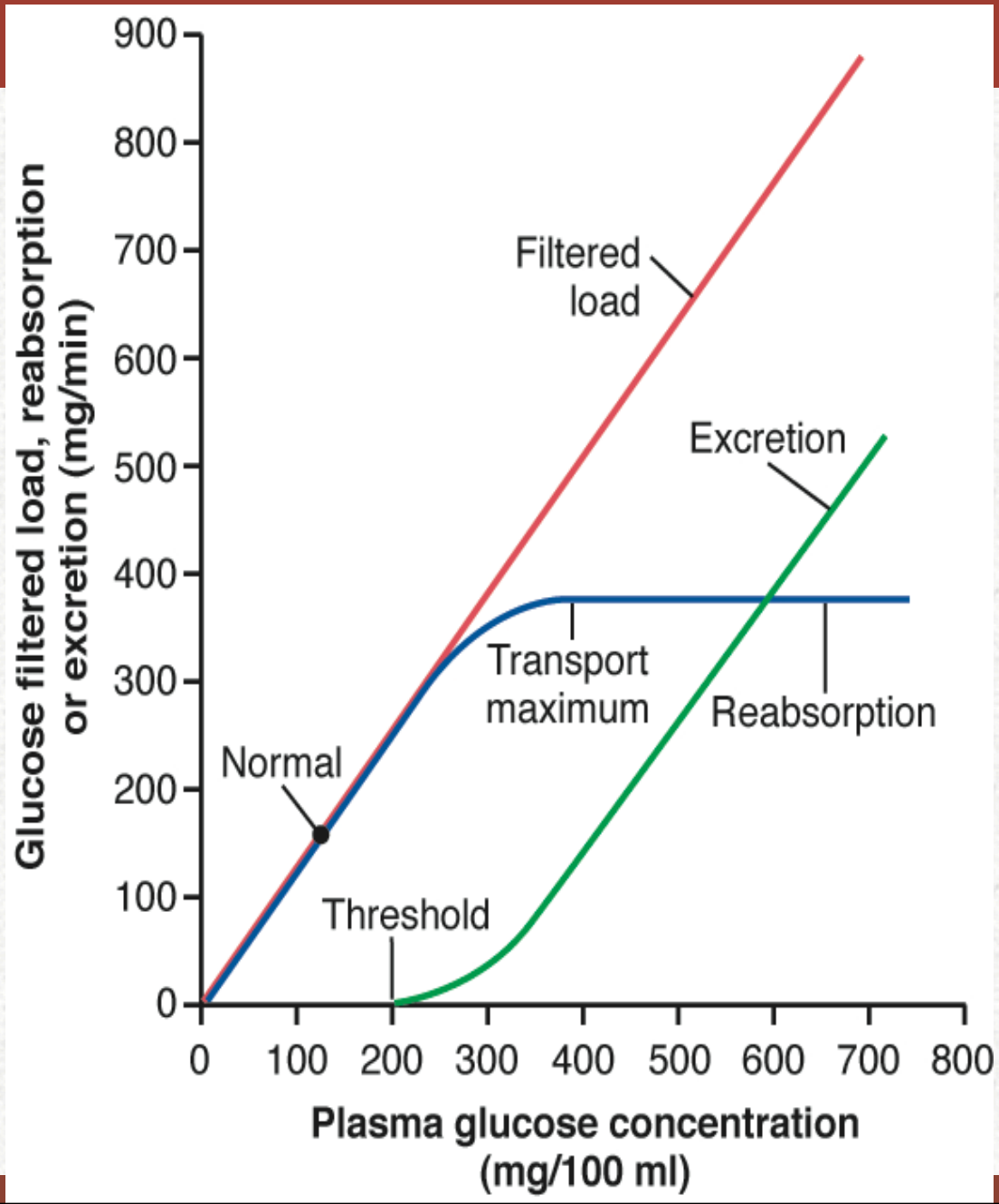
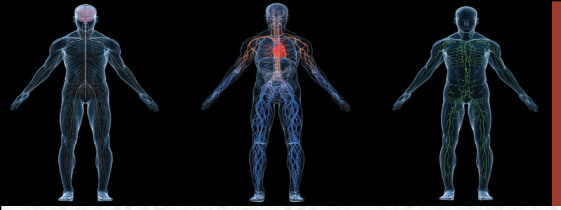
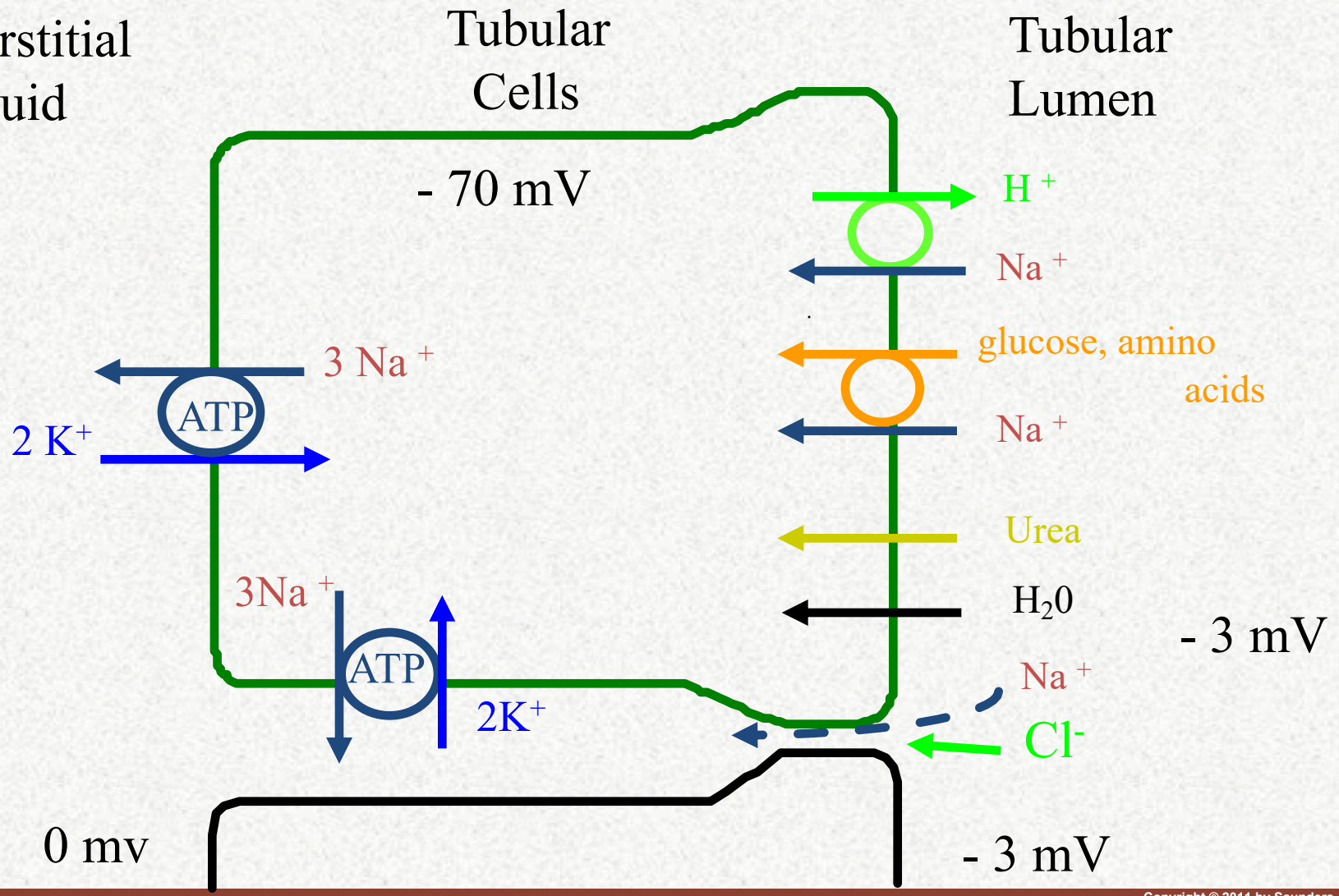


Figure 27-4



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



Mechanisms by which water, chloride, and urea reabsorption are coupled with sodium reabsorption

sodium reabsorption → increasing the osmolality → driving force to reabsorb water →
This sodium and water reabsorption:

- increases the luminal chloride concentration → now there's high negative charge in the lumen → driving force for chloride to be passively reabsorbed (so chloride follow sodium)
- increases luminal urea concentration (because water, the solvent, decreased, it was reabsorbed) → passive urea reabsorption in the proximal convoluted tubule

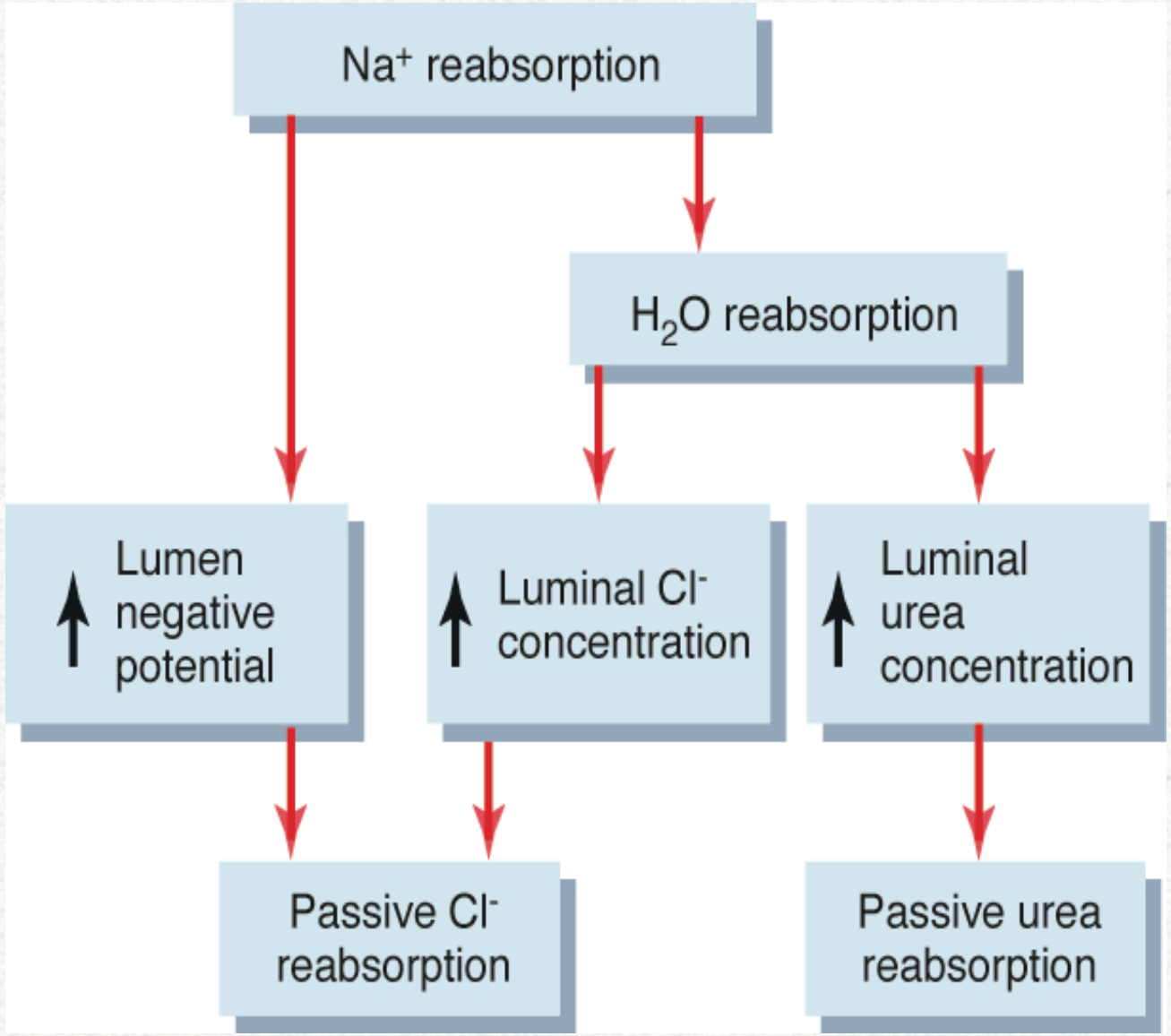
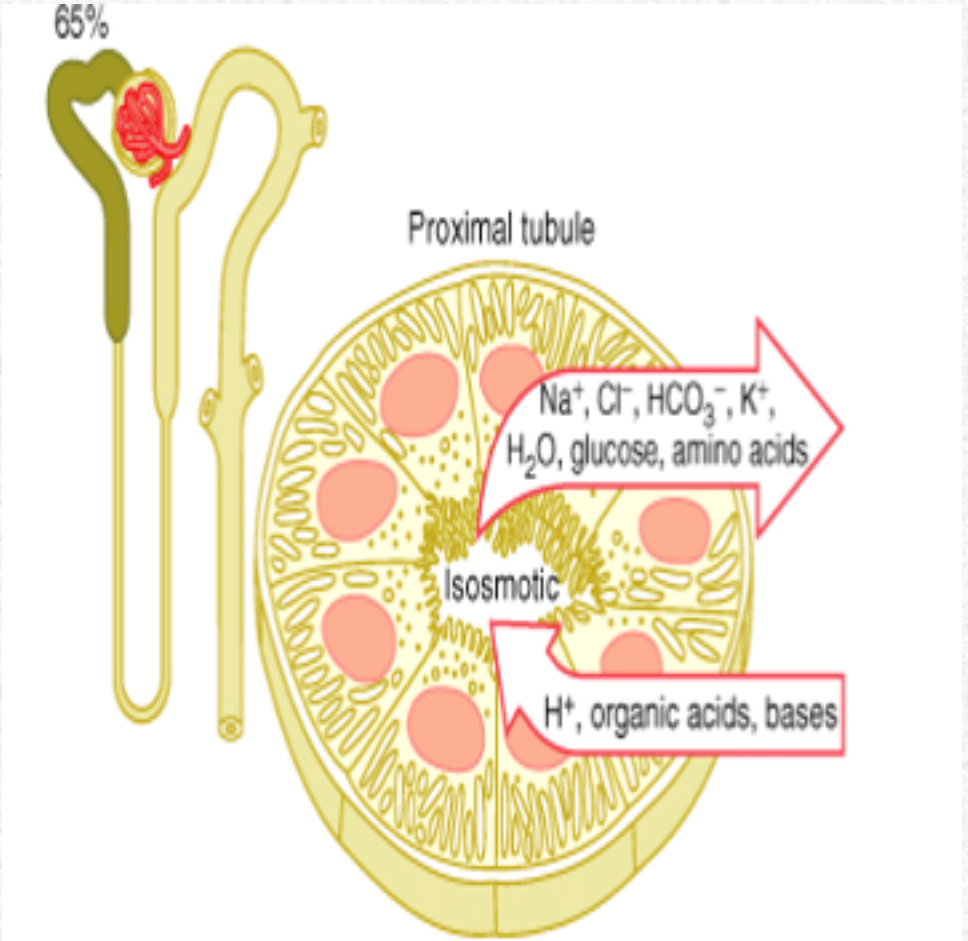


Figure 27-5

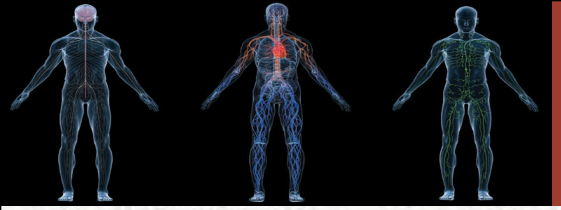
Proximal Tubules

- 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.

Notice: there's secretion for hydrogen and organic acids & bases and this secretion is highly selective and secondary active



Changes in concentration in proximal tubule

X axis:
zero: the beginning of the proximal convoluted tubule
50%: the middle of the convoluted tubule
100% at the end of the proximal convoluted tubule

Y axis: tubule fluid concentration of a substance / plasma concentration of that substance
So this ratio is measured for different substance in the different parts of the proximal convoluted tubule

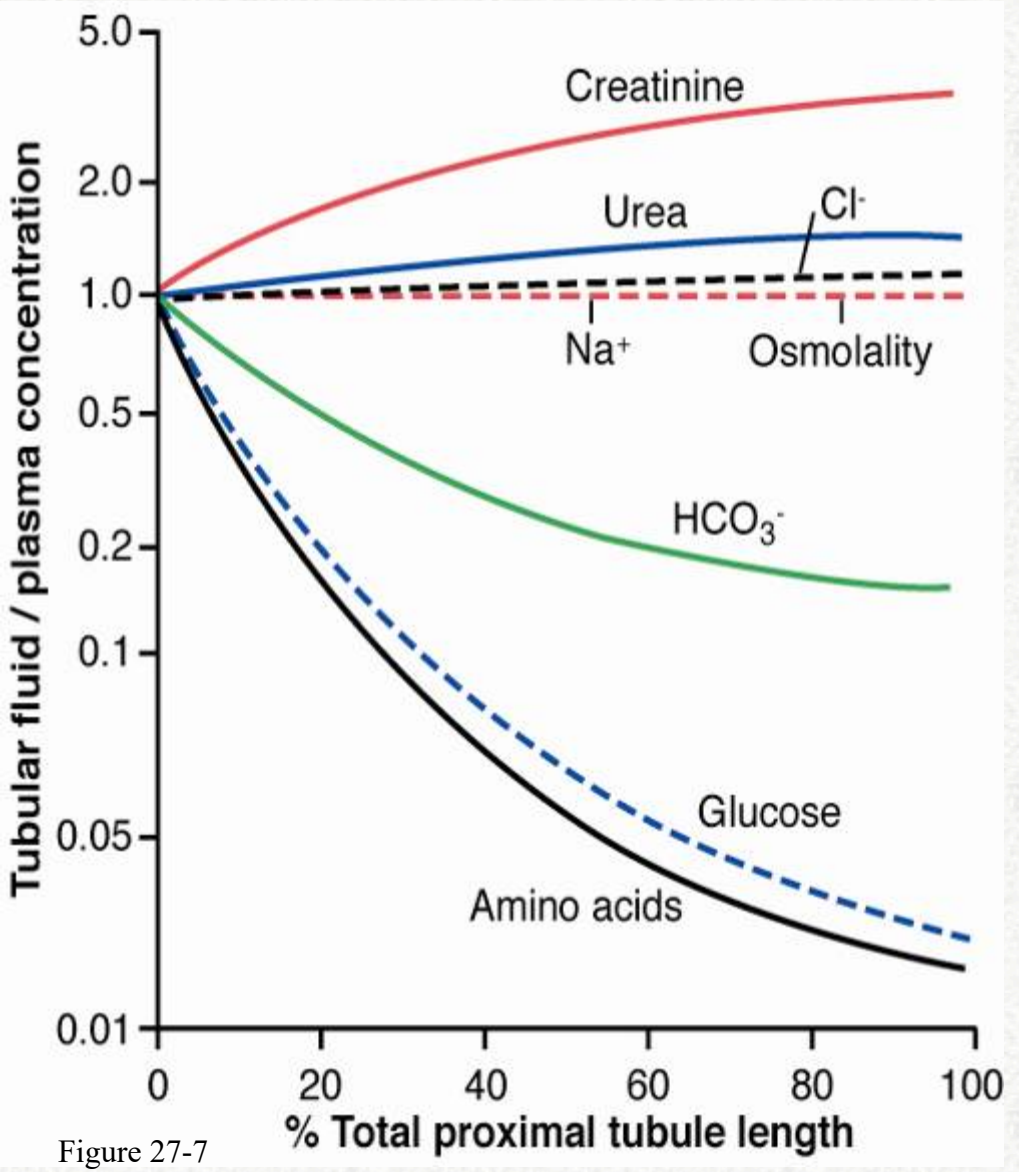
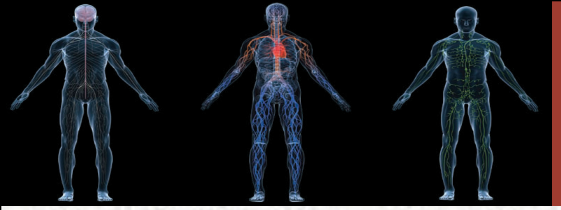


Figure 27-7



Changes in concentration in proximal tubule

The ratio for a substance is close to 1 means that the tubule fluid of that substance is close to its plasma concentration

- Sodium and chloride ratios are close to 1 (70% of sodium and chloride is reabsorbed)

Creatinine (which is a waste): its ratio is more than 1 and it increases along the tubule

- It's more than 1: so creatinine concentration in the tubular fluid is higher than its plasma concentration (because it's poorly reabsorbed)
- It increases along the tubule: because water, the solvent, is being reabsorbed

Bicarbonate's ratio: less than 1

Glucose and amino acids' ratios: less than 1 and it almost reaches zero at the end (their tubular fluid levels decreases a lot because of their high reabsorption [100%])

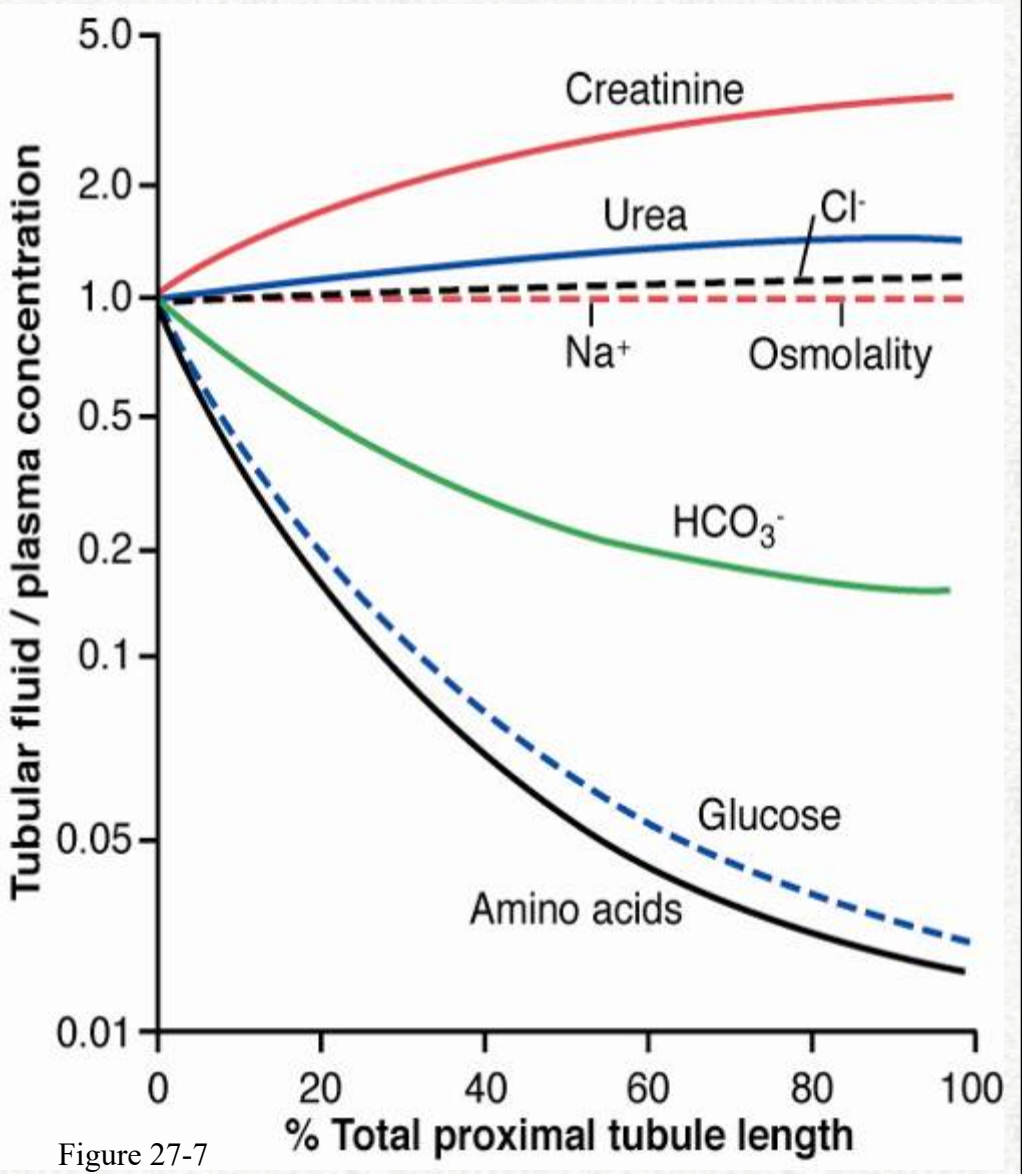
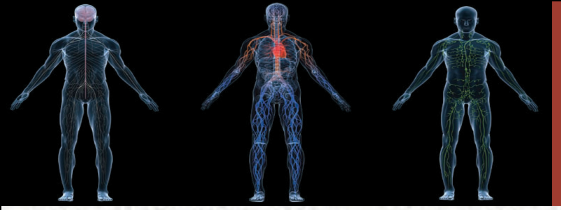


Figure 27-7



Loop of Henle

This last slide will be explained in the next lecture - skip it and jump to the next lecture

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^+