Renal Physiology 5

Transport Processes in Nephron

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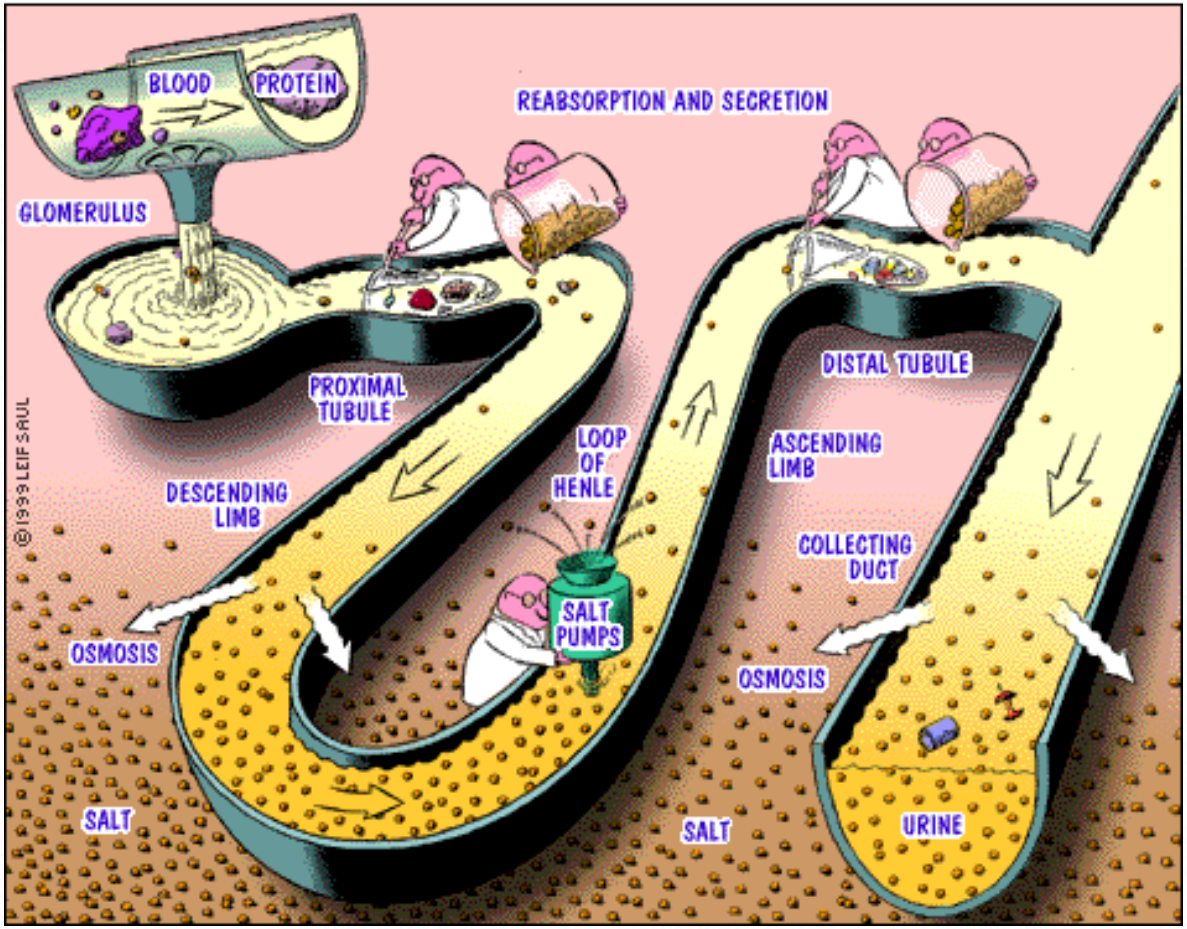
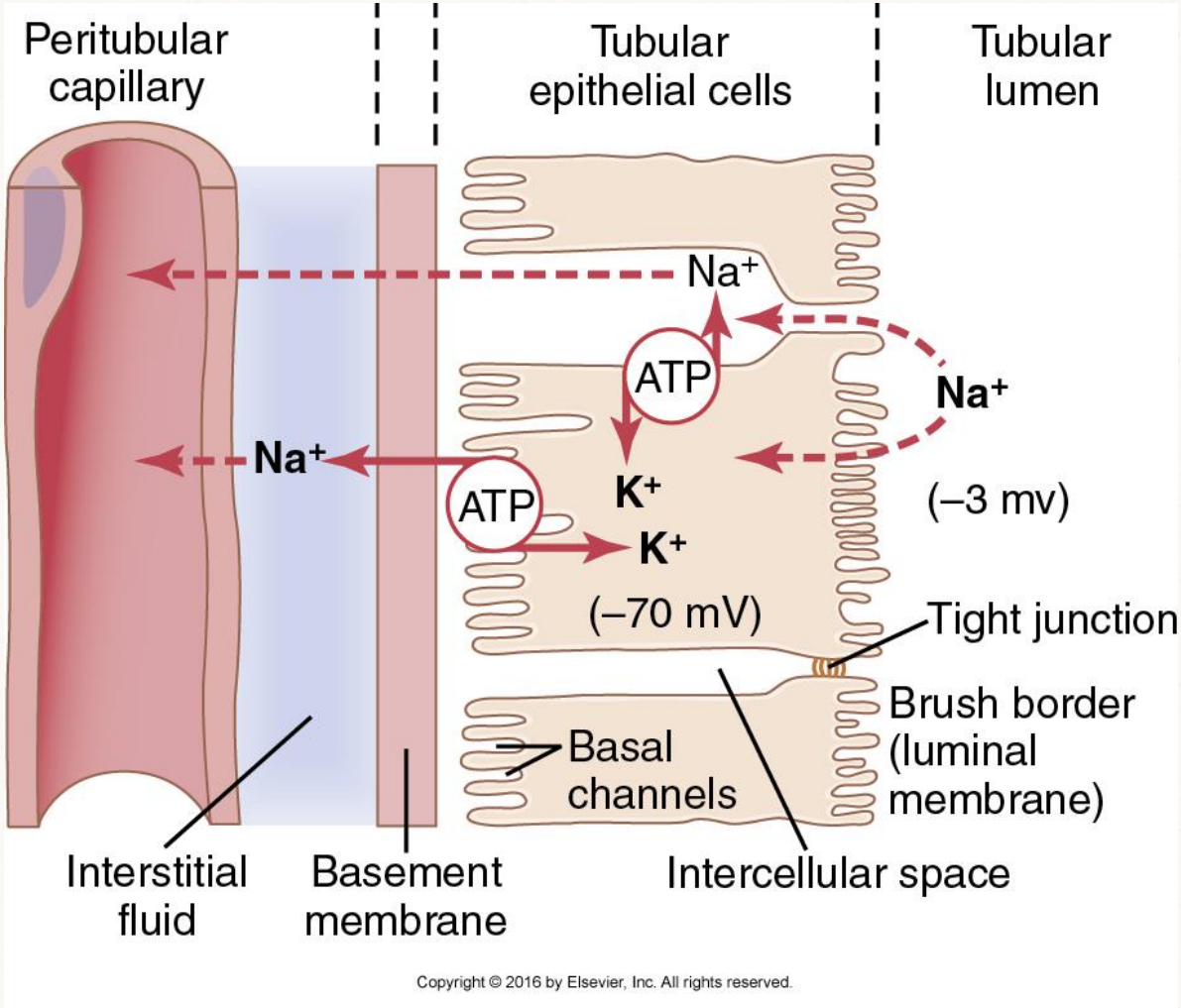


Learning Objectives:

- Define tubular reabsorption, tubular secretion, transcellular and paracellular transport.
- Identify and describe mechanisms of tubular transport.
- Describe tubular reabsorption of sodium and water.
- Revise tubulo-glomerular feedback and describe its physiological importance.
- Identify and describe mechanism involved in Glucose reabsorption.
- Study glucose titration curve in terms of renal threshold, tubular transport maximum, splay, excretion and filtration.
- Identify the tubular site and describe how Amino Acids, HCO3-, P04- and Urea are reabsorbed.

Reabsorption

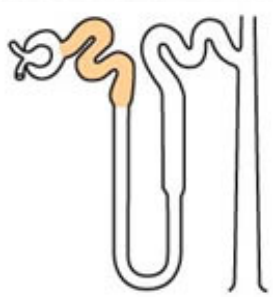


Bulk flow results from the imbalance of osmotic or hydrostatic forces at the peritubular capillary.

Transport process in the nephron

Proximal convoluted tubule

Early PCT

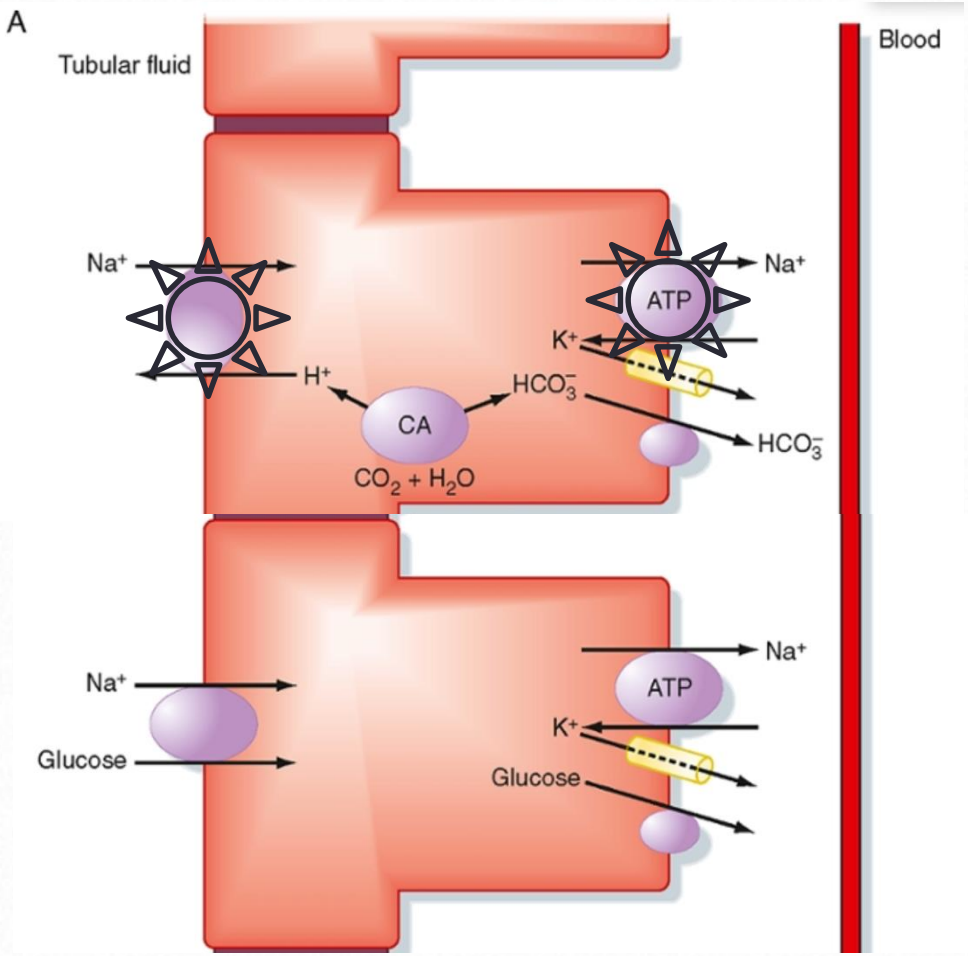


~70% of Na^+, Cl^-, K^+ and water

1. **NHE** (Na^+ for H^+, HCO_3^- reabsorbed.

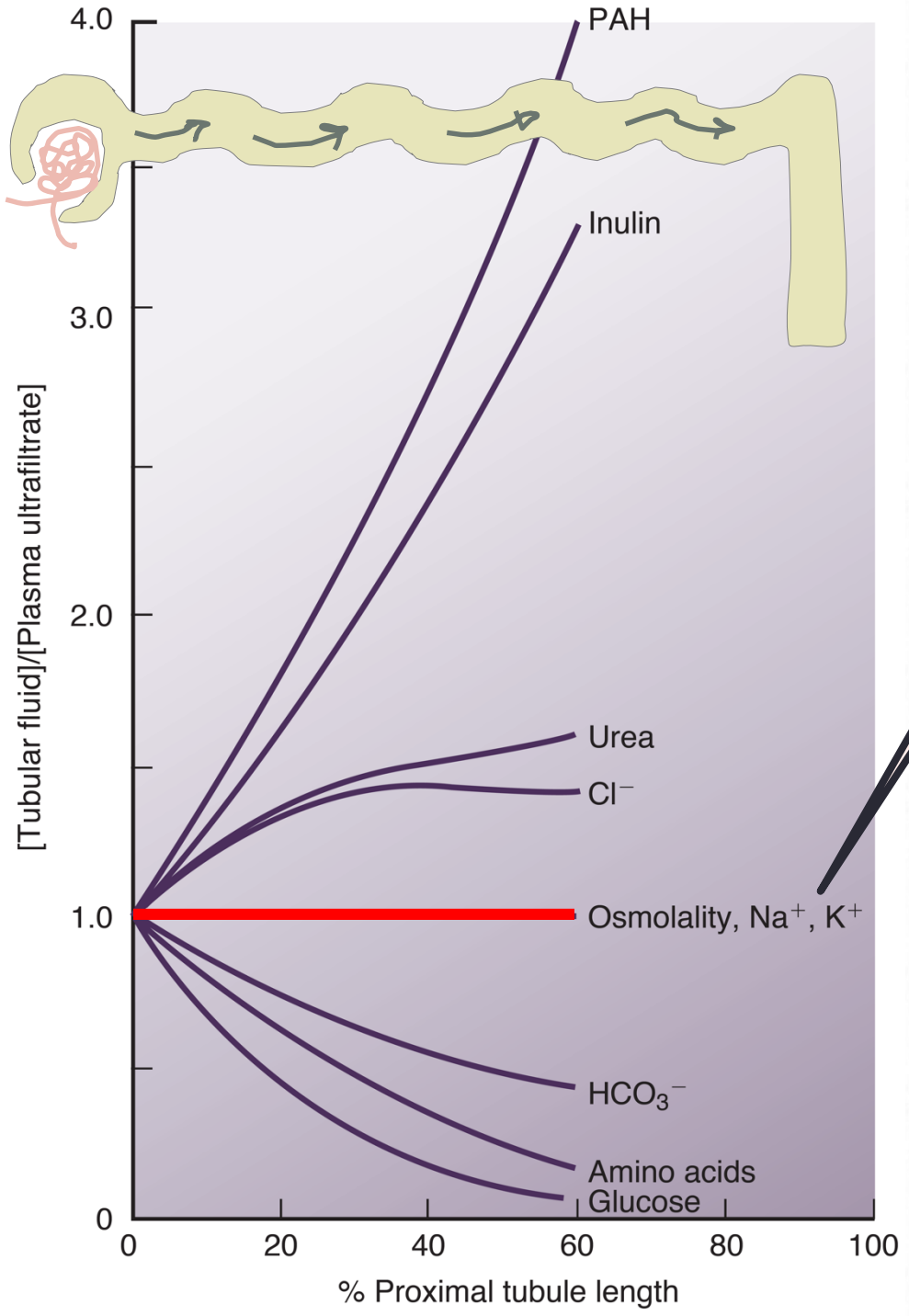
2. **Symporters**: Na^+-glucose, Na^+-amino acid, Na^+-Pi, Na^+-lactate

Organic molecules will be completely removed from the filtrate in the first half of the PT



passive transport mechanisms

Absorption in PCT



The *amount* of Na^+ in the tubular fluid ⬇⬇ along PCT

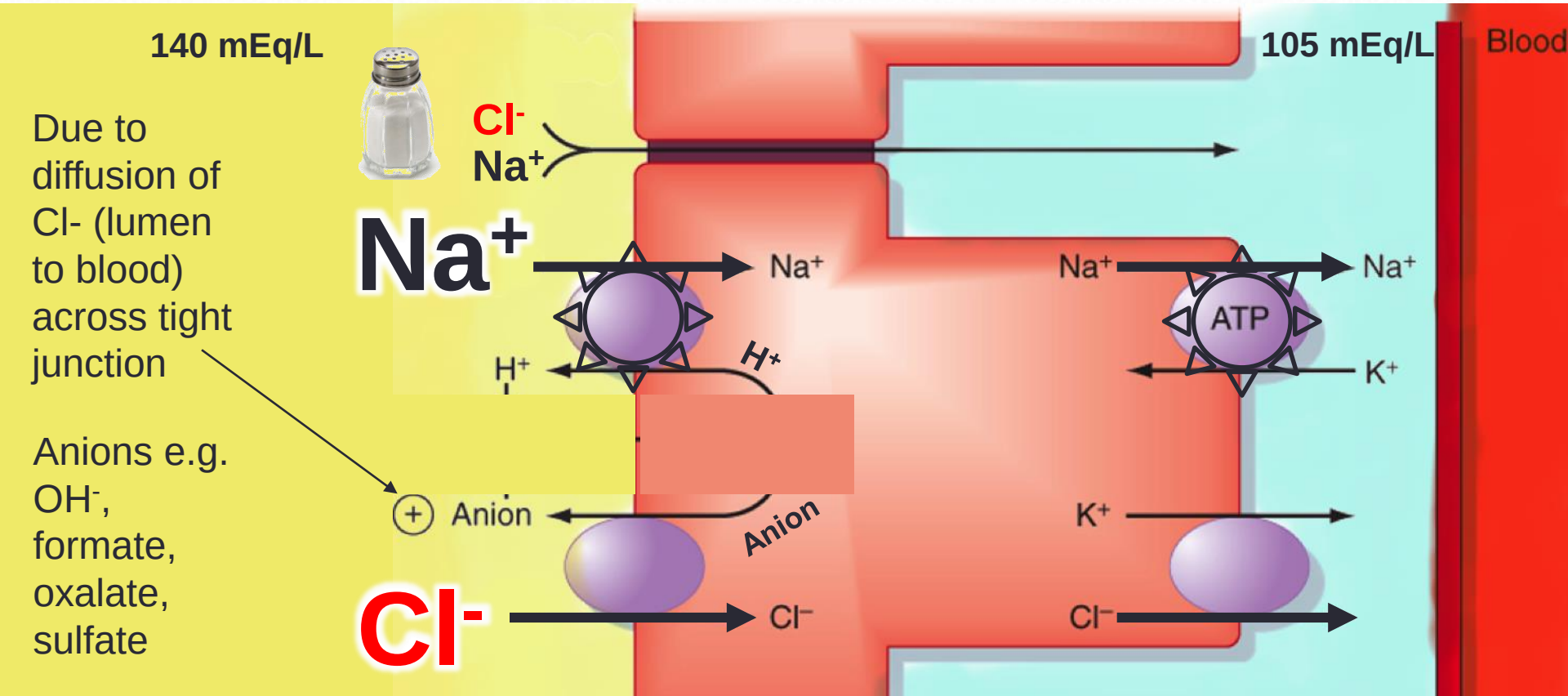
The [Na^+] (and total osmolarity) remains relatively **constant**

Because water permeability of PCT is so great → **water reabsorption keeps pace with Na^+ reabsorption.**

Late PCT

- Na^+ Reabsorbed with Cl^- Why? due to different transport mechanisms in late PCT, lack of organic molecules

Transcellular and **Paracellular**

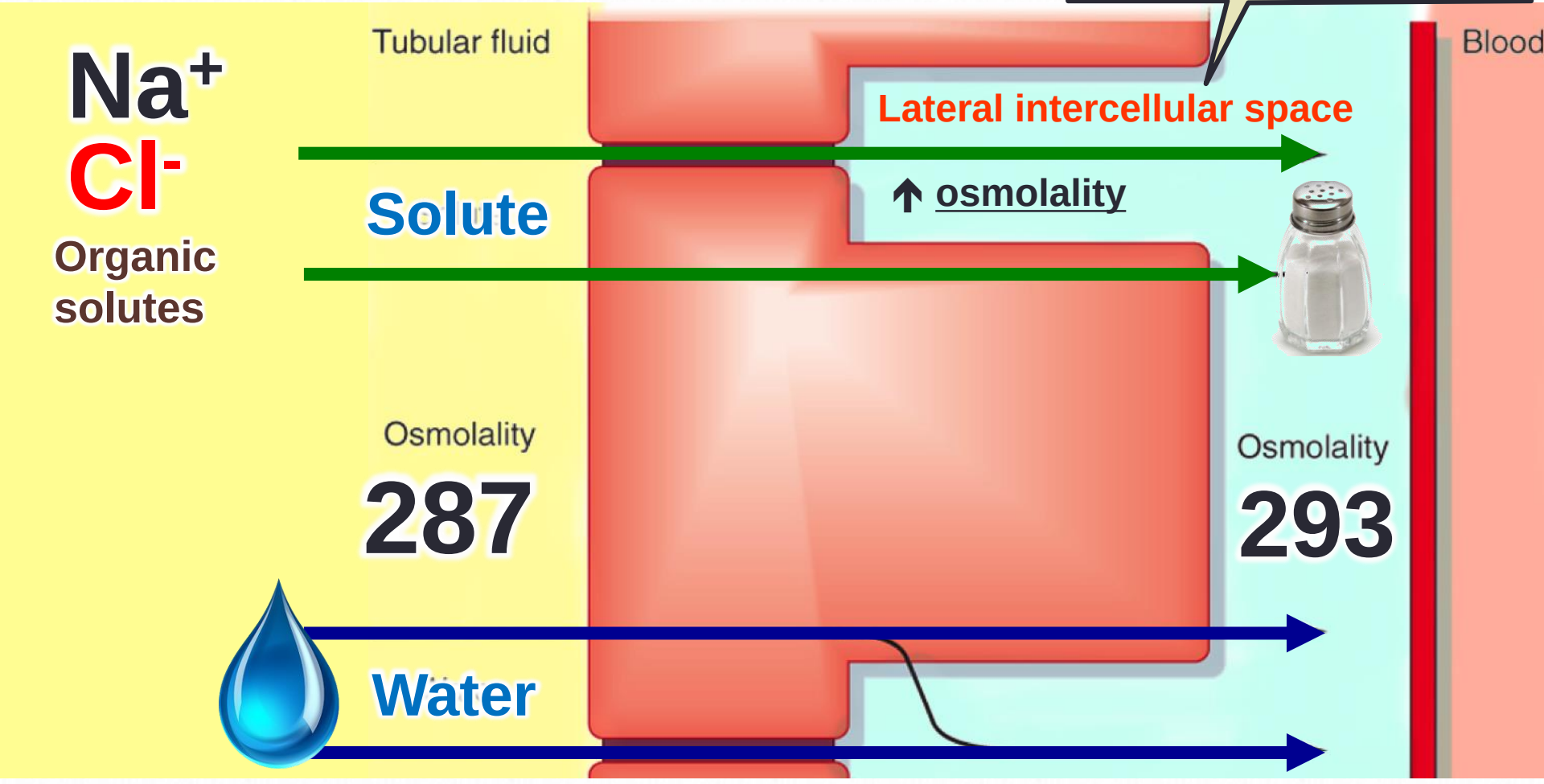


Water reabsorption

PCT

Passive, due to osmoticaly active substances that are absorbed

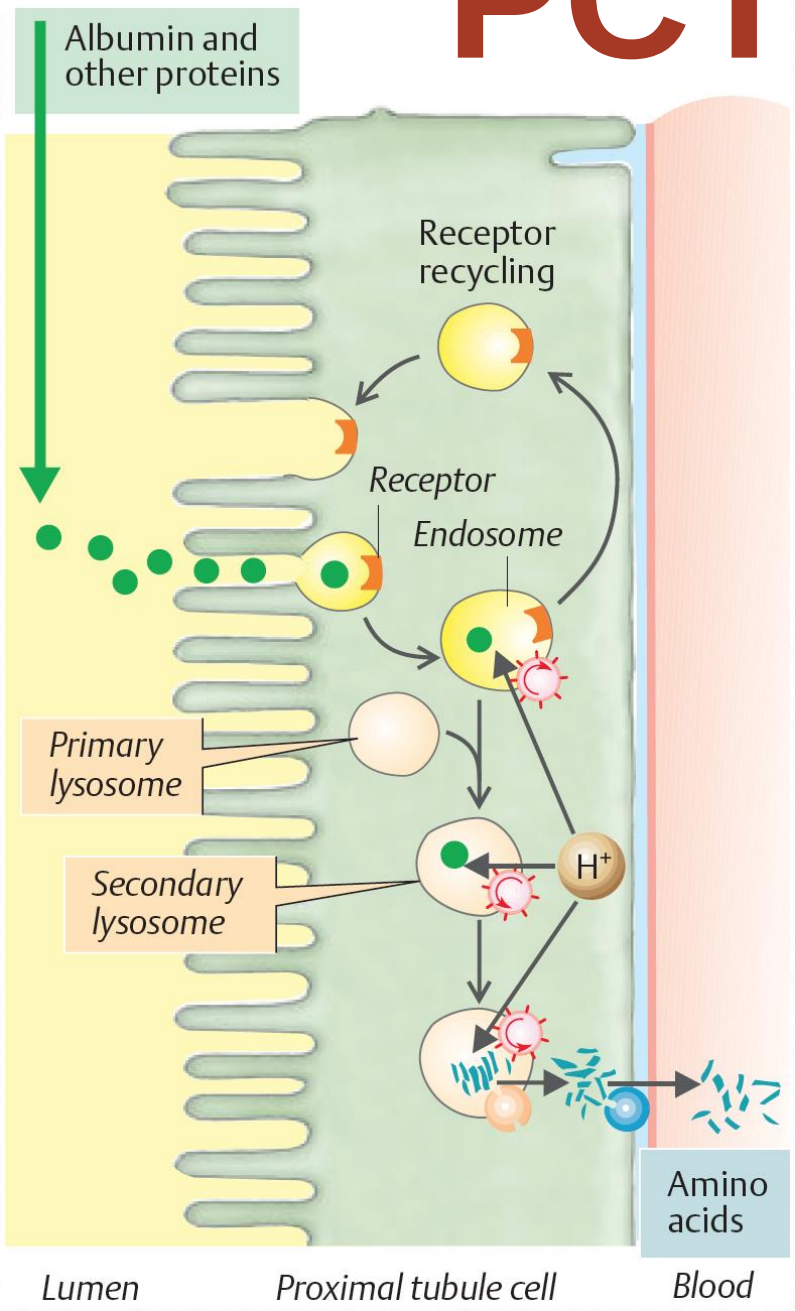
The driving force for osmotic water reabsorption



Protein reabsorption

PCT

- Peptide hormones, small proteins & amino acids
- **Endocytosis** either intact or after being partially degraded by enzymes.
- Has a maximum capacity - too much protein filtered = **proteinuria**



Organic anion/cation secretion PCT

Endogenous compounds e.g. cAMP, Bile salts, Creatinine, adrenaline, noradrenailne.

Exogenous compounds e.g. Penicillin, NSAIDs, Morphine, PAH.

Small proportion are eliminated via **excretion** after **filtration** alone. **Why?**

Bind to plasma proteins - not readily filtered.

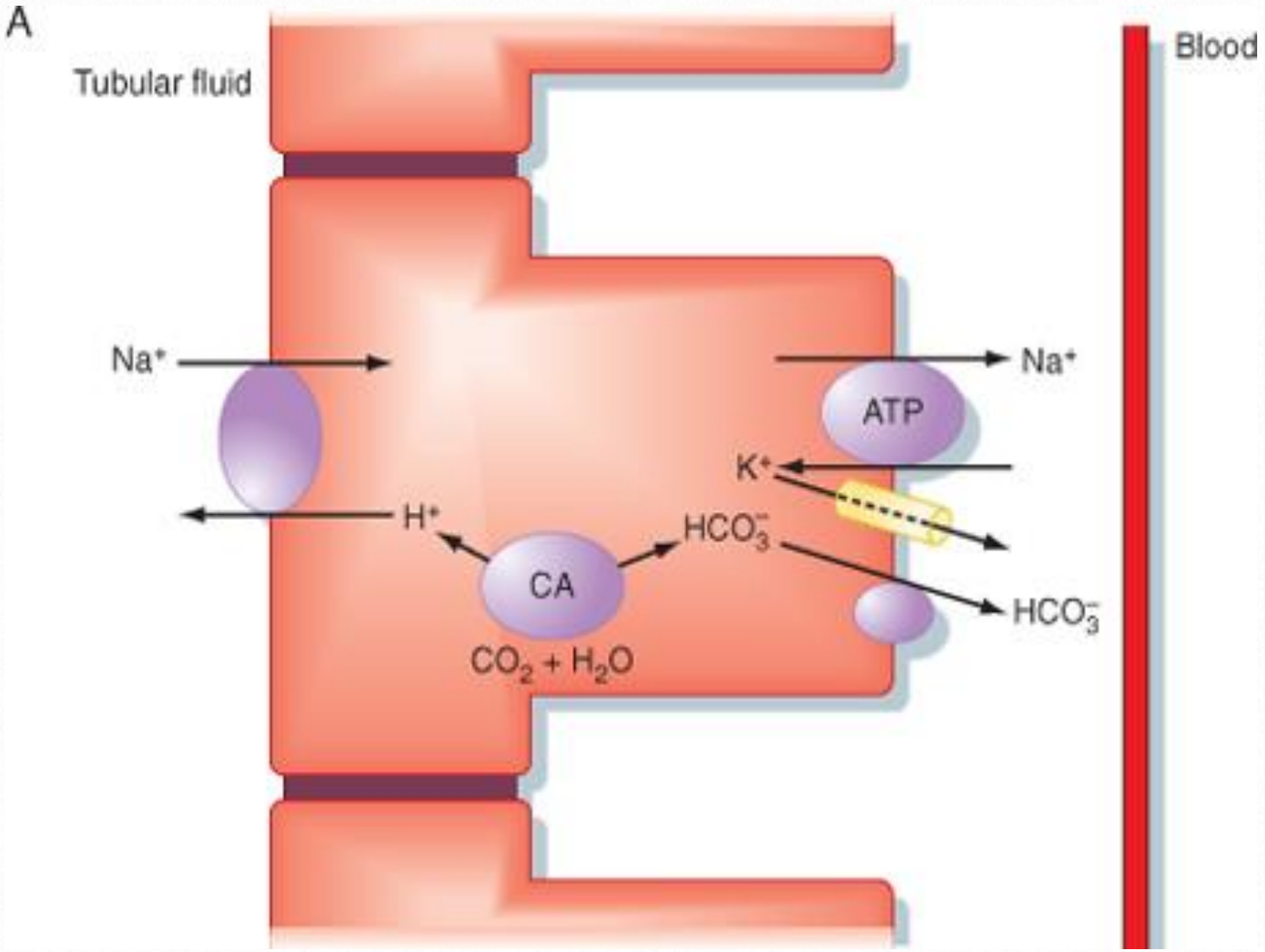
All are **secreted** from the peritubular capillary into tubular fluid.

HCO_3^- reabsorption

- The renal tubules are poorly-permeable to HCO_3^-. However, it is still reabsorbed but in the form of CO_2 (to which the tubules are very highly permeable).

This occurs through the following steps:

1. H^+ is formed inside the cells then secreted in the tubular fluid.
2. H^+ combines with HCO_3^- in the tubular fluid forming H_2CO_3.


A
Tubular fluid
Blood
Na+
Na+
ATP
K+
H+
HCO3−
CA
HCO3−
CO2 + H2O

HCO_3^- reabsorption

3. By activity of the **carbonic anhydrase enzyme (C.A.)** in the tubular cells, H_2CO_3 dissociates into CO_2 & H_2O.

4. CO_2 diffuses into the cells where it combines with H_2O (by activity of an intracellular C.A.), forming H_2CO_3 which dissociates into HCO_3^- & H^+.

5. HCO_3^- passively diffuses into the interstitial fluid (then to the blood) while H^+ is secreted into the tubular fluid to help more reabsorption of HCO_3^-.

HCO_3^- reabsorption

- Factors affecting **HCO_3^-** reabsorption:

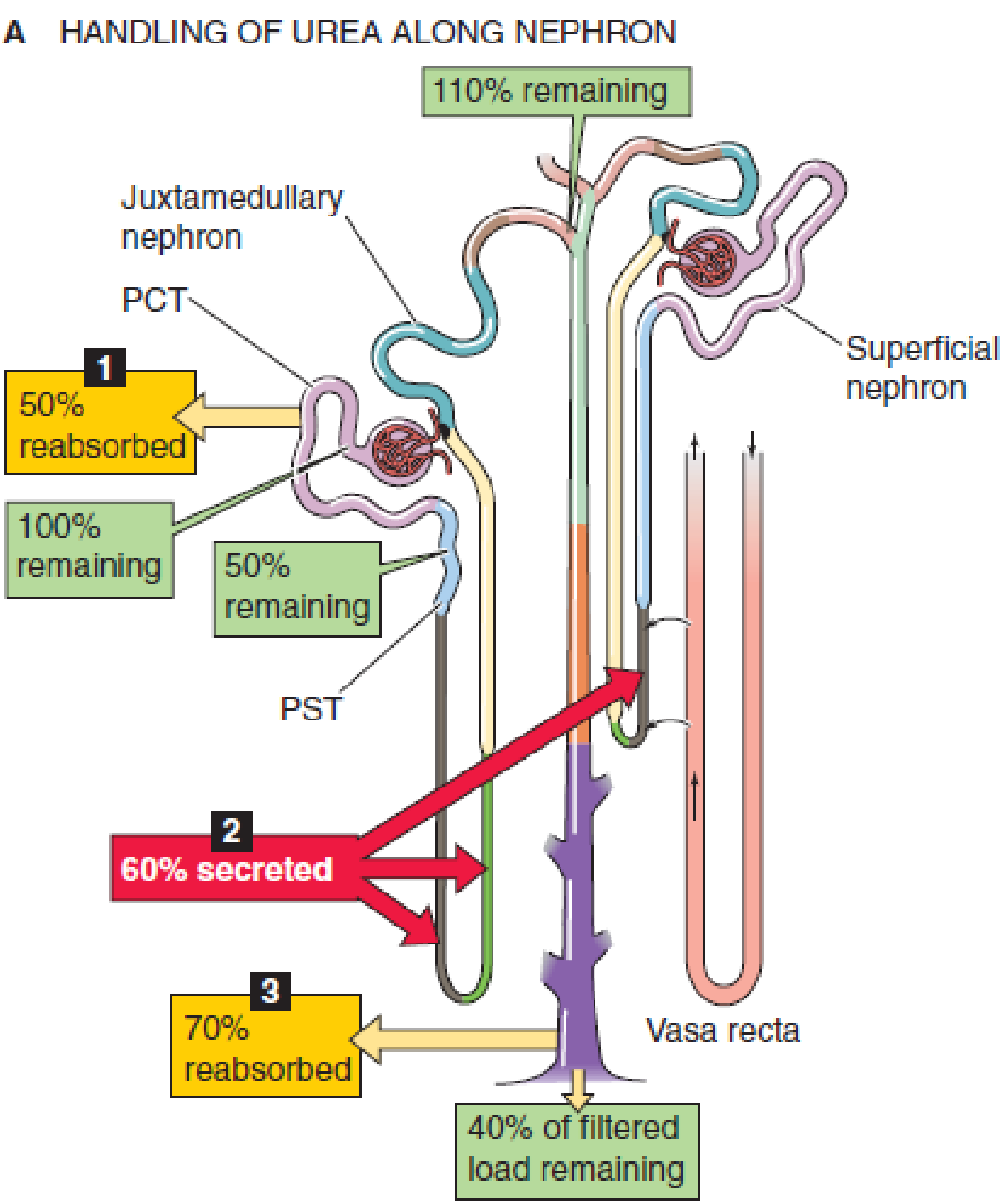
1. Arterial Pco_2
2. Plasma[K^+]
3. Plasma Aldosterone.
4. Plasma [Cl^-]

Urea Reabsorption

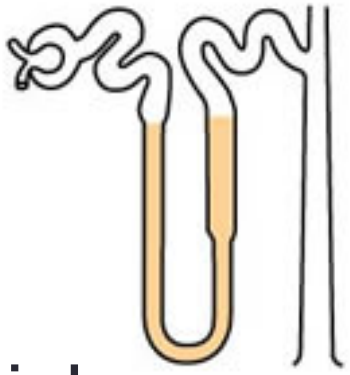
- Normal plasma level of urea 2.5-6.5 mM/L (15-39 mg/100ml)

Mechanism of urea reabsorption:

- About **40-70%** of filtered load of urea is reabsorped in:
  - Second half of PCT.
  - Medullary CT and CD (ADH dependent)
- Due to water reabsorption in the first half of PCT, the conc. of urea is increased in the second half and urea is reabsorbed by simple diffusion (downhill)


A HANDLING OF UREA ALONG NEPHRON
110% remaining
Juxtamedullary nephron
PCT
Superficial nephron
1
50% reabsorbed
100% remaining
50% remaining
PST
2
60% secreted
3
70% reabsorbed
Vasa recta
40% of filtered load remaining

Loop of Henle



25% of filtered **NaCl** and **K^+** is reabsorbed as well as Ca^{2+}, HCO_3^- in thick ascending limb (TAL)

- The ascending limb is **impermeable to water (diluting segment).**

- 15% water absorbed in thin descending limb (**permeable to water**)

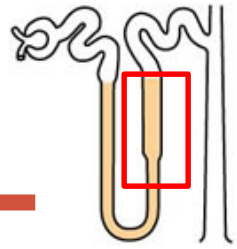
The descending thin limb does not reabsorb NaCl

Solute absorption:

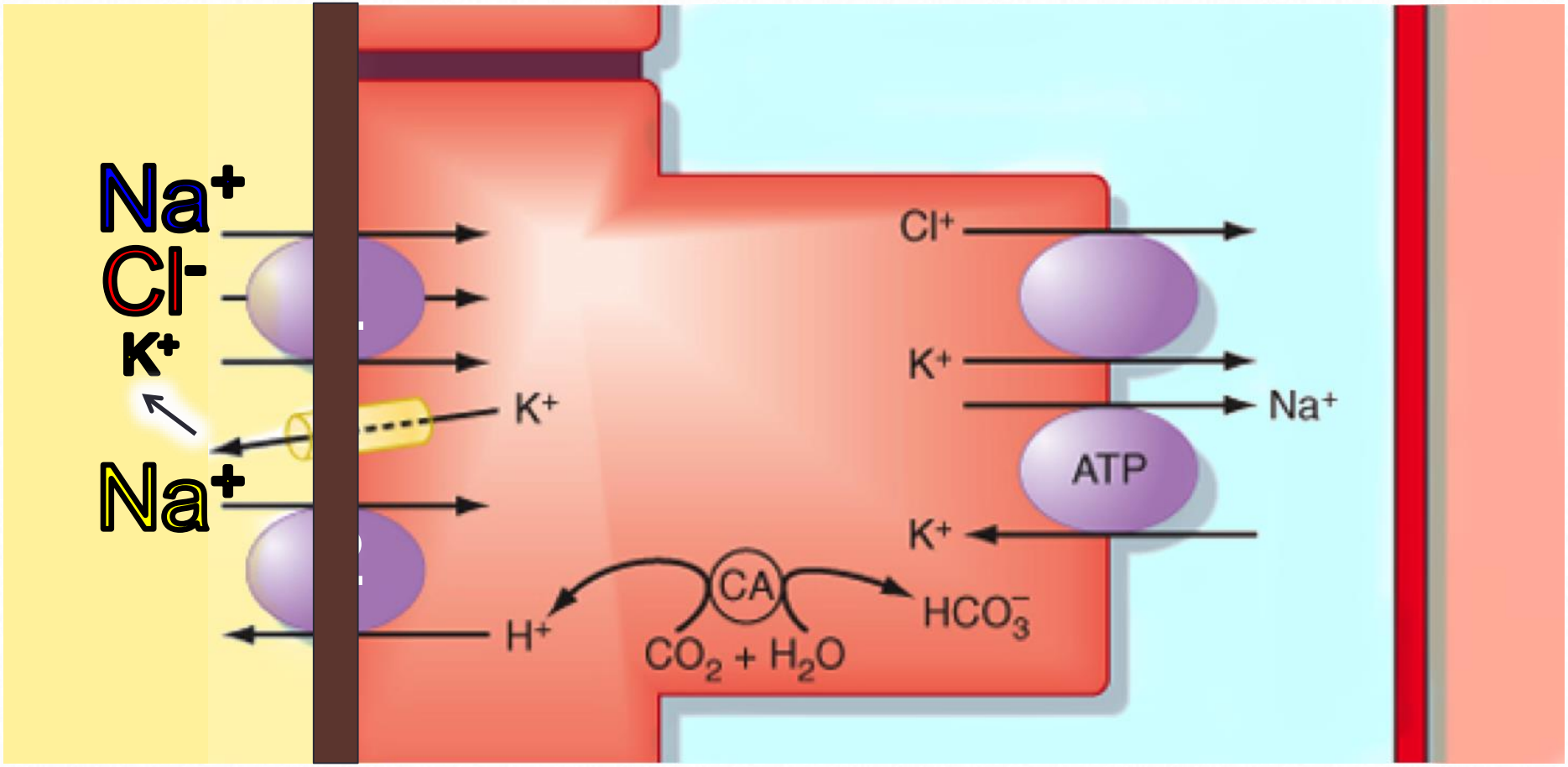
1) **Transcellular (50%)**

- $1Na^+$-$2Cl^-$-$1K^+$ cotransporter
- NHE

TAL



Key element
Na^+/K^+-ATPase

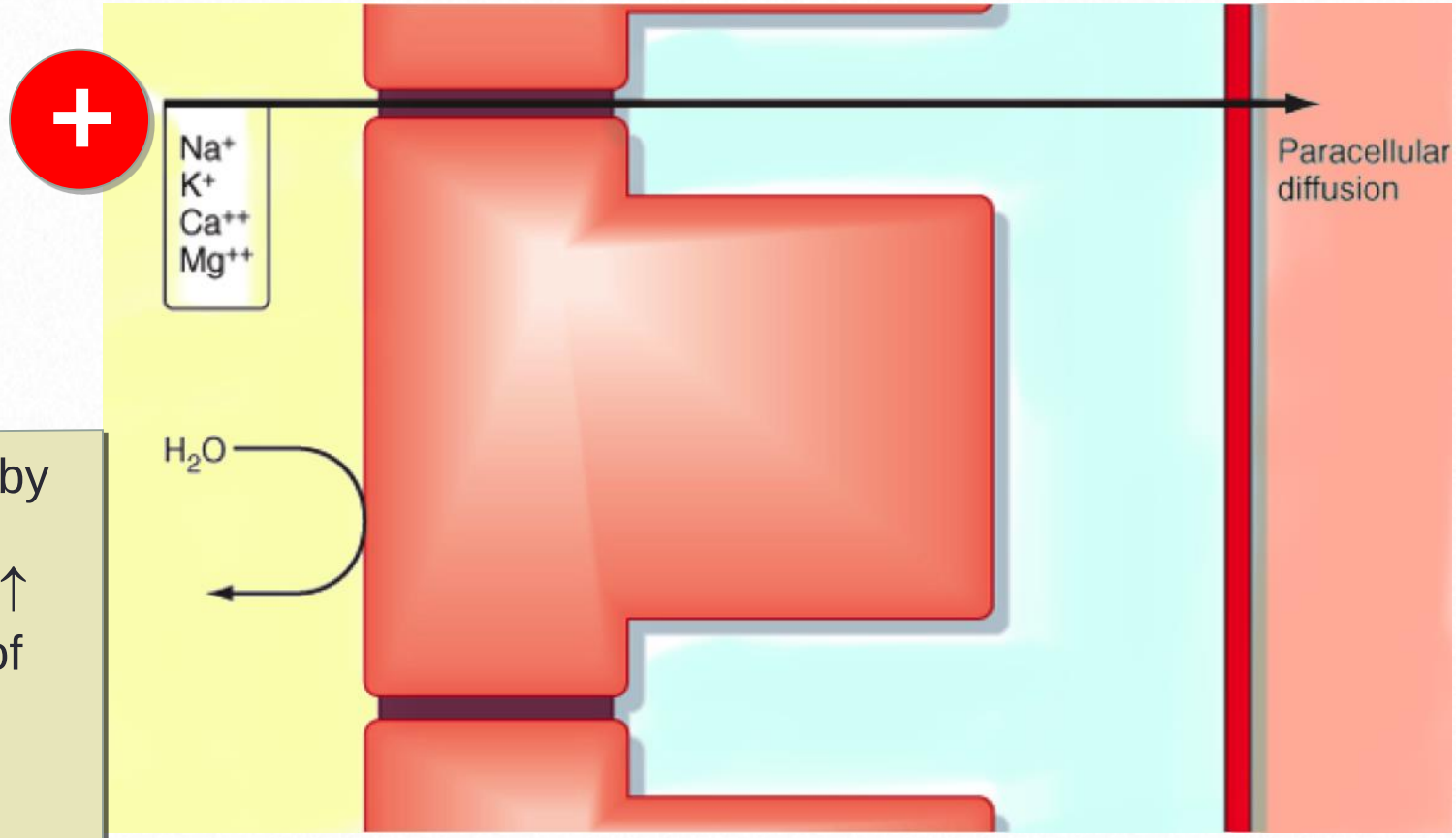


Transport mechanisms for NaCl reabsorption in the thick ascending limb of Henle's loop.

TAL

2) **Paracellular** **(50%)**

Loss of NaCl in tubule ⇒ ↑ +ve compared to blood drives absorption



↑ salt transport by the thick ascending limb ↑ the magnitude of the positive charge in the lumen

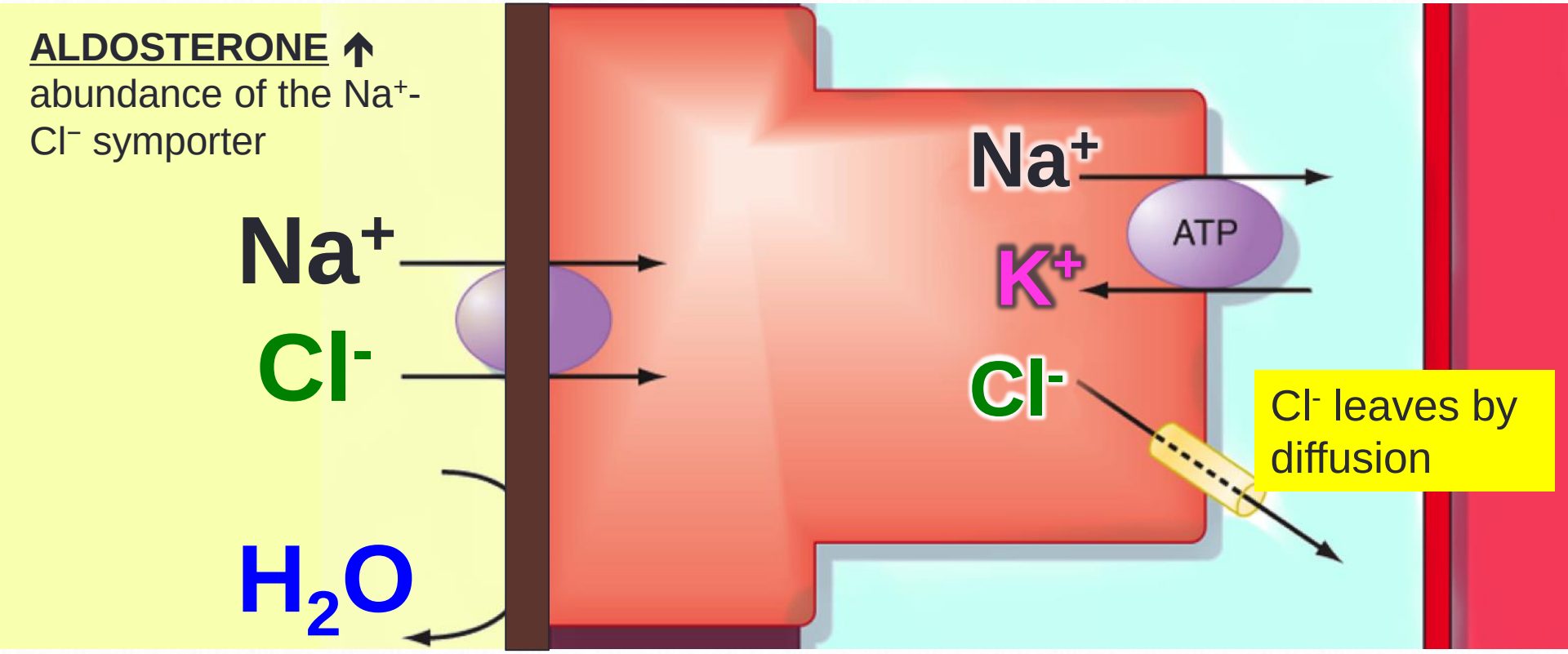
Distal convoluted tubule & collecting duct

DCT & CD

Reabsorb **8%** of filtered NaCl, ~10% water (**needs ADH**)
Some K^+, H^+ secreted ***into*** tubule

Early DCT

This segment is impermeable to water
Reabsorbs Na^+, Cl^- and Ca^{2+}



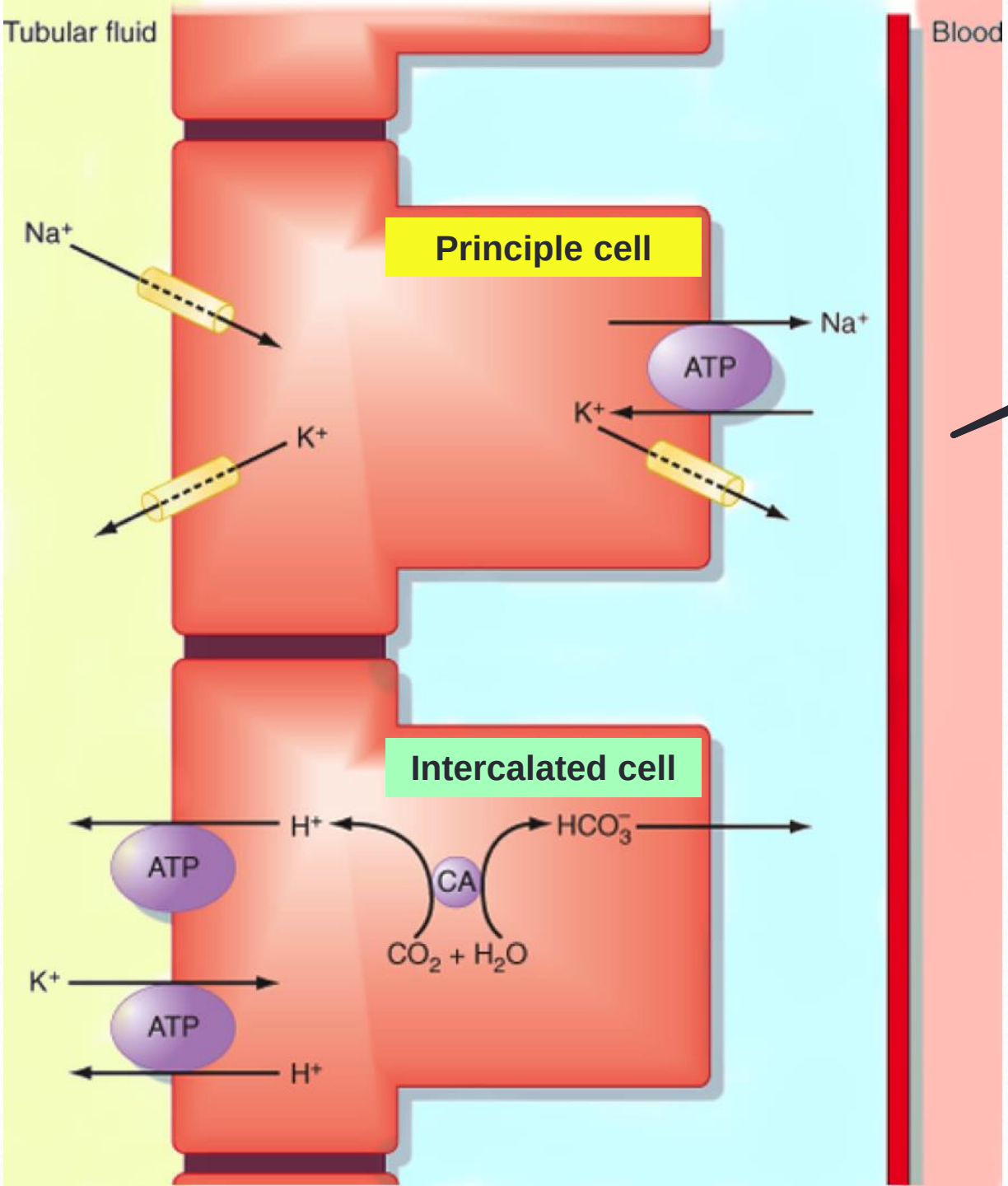
Late DCT

2 cells

1) principle cells: reabsorb Na^+, water, secrete K^+

2) intercalated cells: secrete or reabsorb H^+ (opposite for HCO_3^-) [**important for acid base**], reabsorb K^+

- Na^+ diffuses via selective channels
- K^+ secreted down concentration, reabsorbed by an H^+/K^+-ATPase located in the apical cell membrane



Late DCT

ALDOSTERONE ↑
NaCl reabsorption

How?

↑ **the amount of Na^+/K^+-ATPase** in the basolateral membrane

↑ **expression of the ENaC** in the apical cell membrane

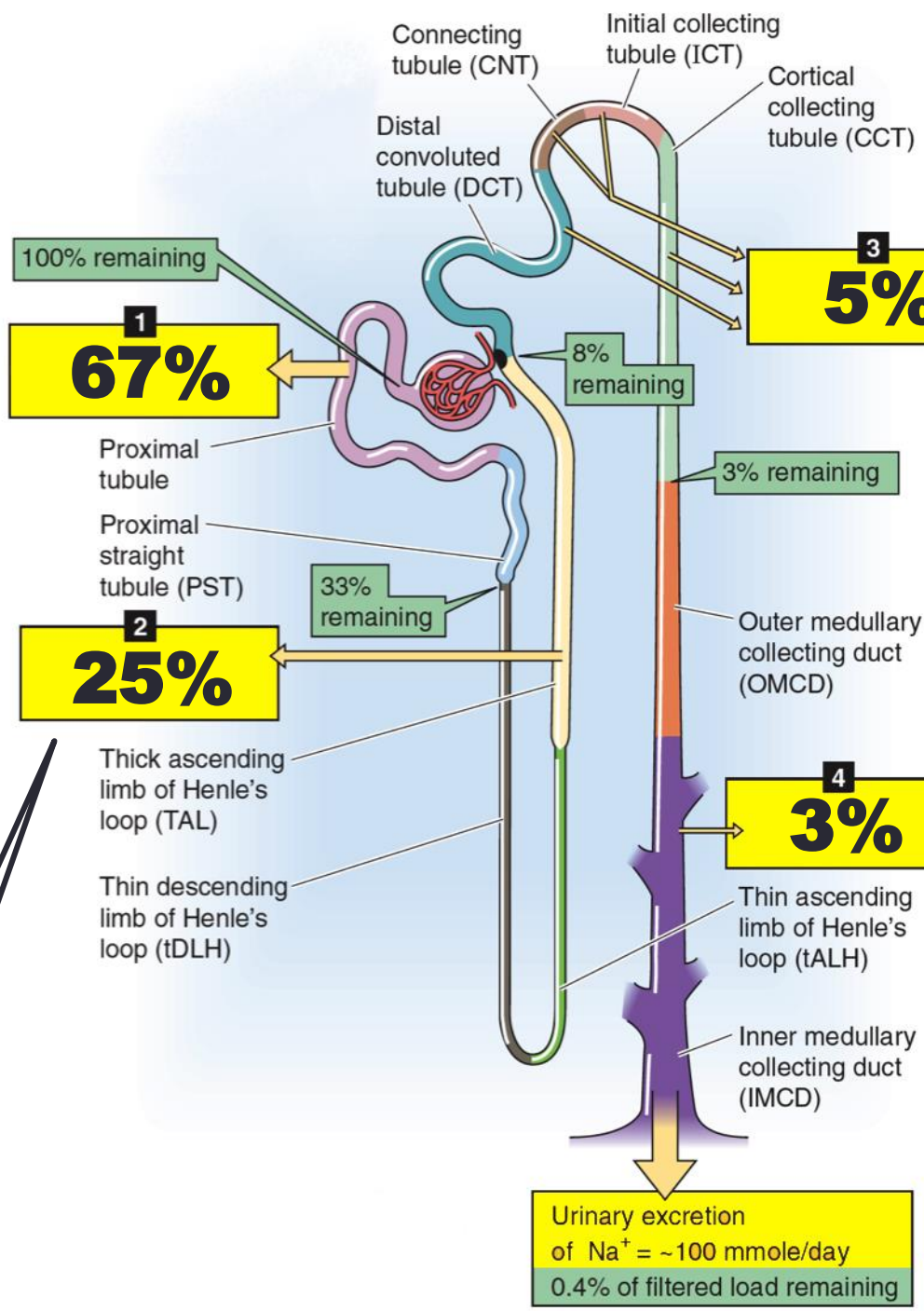
Na^+-H^- exchanger (NHE)

Na^+-glucose
Na^+-amino acid
Na^+-Pi
Na^+-lactate

Na^+

Na^+-H^- exchanger (NHE)

Na^+-$2Cl^-$-K^+ symporter



Na^+/Cl^- cotransporter

Na^+ Channels (ENaC)


Thanks