(Renal Physiology 5)

Renal Transport Process

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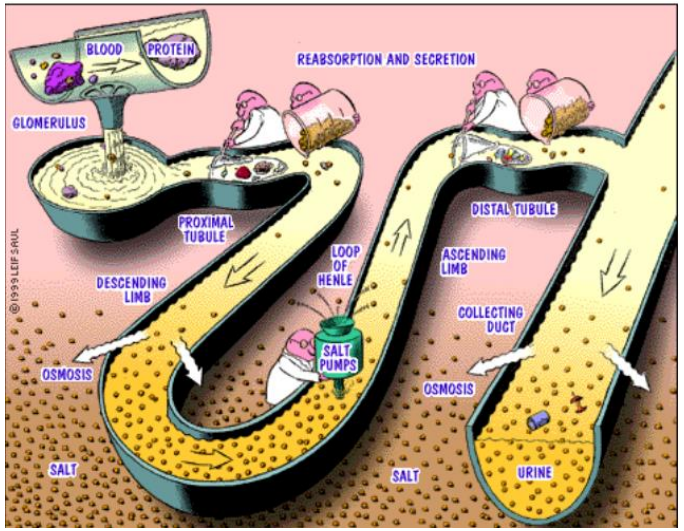


Tubular Reabsorption

All **organic nutrients** are reabsorbed

Water and ion reabsorption is **hormonally controlled**

Reabsorption may be an **active** (requiring ATP) or **passive** process

Tubular Reabsorption

- A trans-epithelial process whereby most tubule contents are returned to the blood

- Transported substances move through three membranes
  - Luminal and basolateral membranes of tubule cells
  - Endothelium of peritubular capillaries

- Ca^{2+}, Mg^{2+}, K^{+}, and some Na^{+} can be reabsorbed via paracellular pathways.

Sodium Reabsorption: Primary Active Transport

- Sodium reabsorption is almost always by active transport
  - Na^+ enters the tubule cells at the luminal membrane
  - Is actively transported out of the tubules by a Na^+-K^+ ATPase pump.
- Other important solutes are linked either directly or indirectly to reabsorption of Na^+.

Proximal convoluted tubule

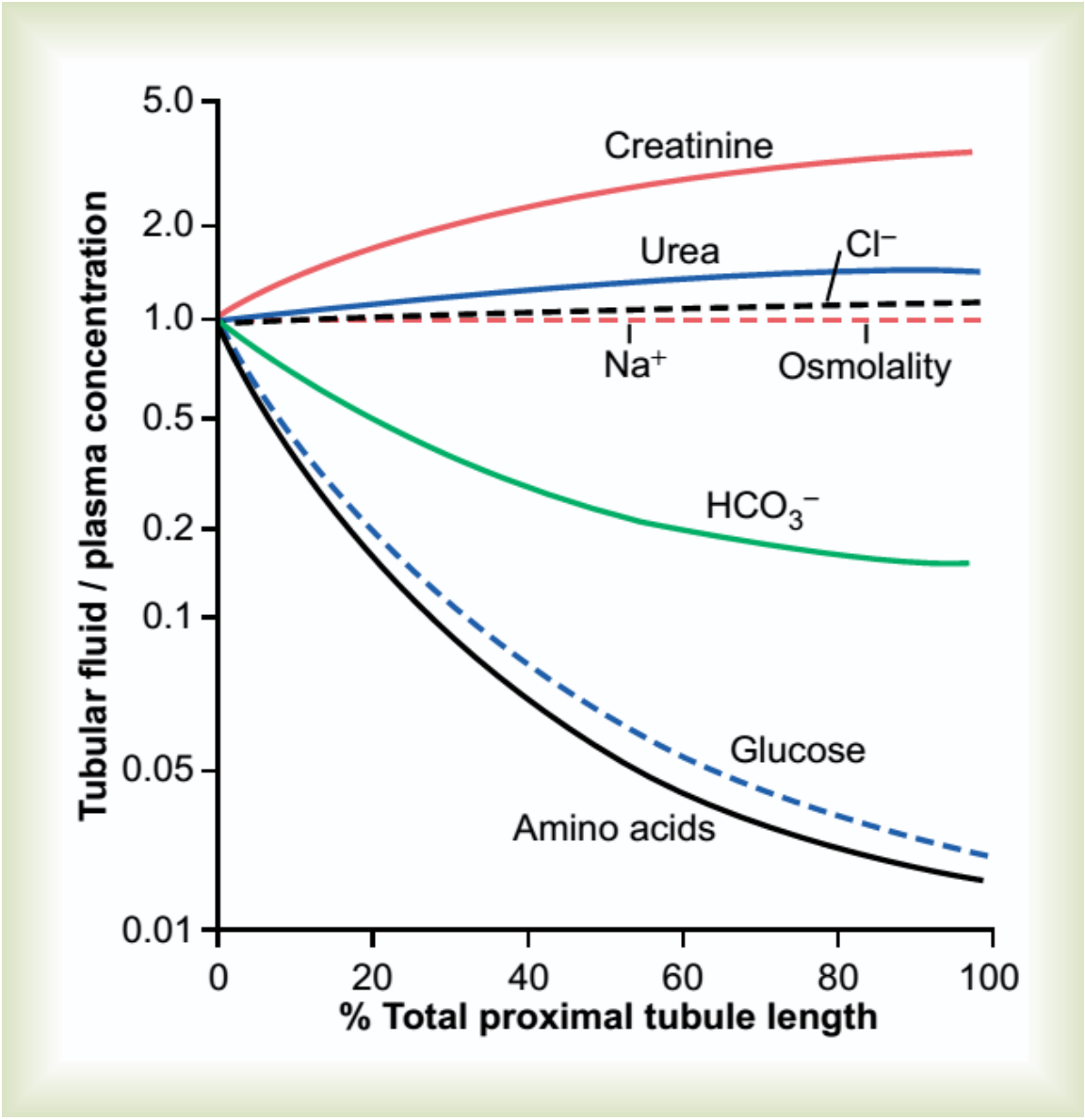
- Leaky epithelium permeable to ions & water
- ~ 70 % of Na+,
- Cl-, K+, water absorbed passively (follows Na+)

- Na+ Reabsorption (transcellular):

Early PCT Na+ absorbed:

1) exchanged with H+,
   but HCO3- reabsorbed
2) with organic substances
   glucose, amino acids, lactate, Pi

} Na^+/K^+-ATPase important


Tubular fluid / plasma concentration
5.0
2.0
1.0
0.5
0.2
0.1
0.05
0.01
0
20
40
60
80
100
% Total proximal tubule length
Creatinine
Urea
Cl⁻
Na⁺
Osmolality
HCO3⁻
Glucose
Amino acids

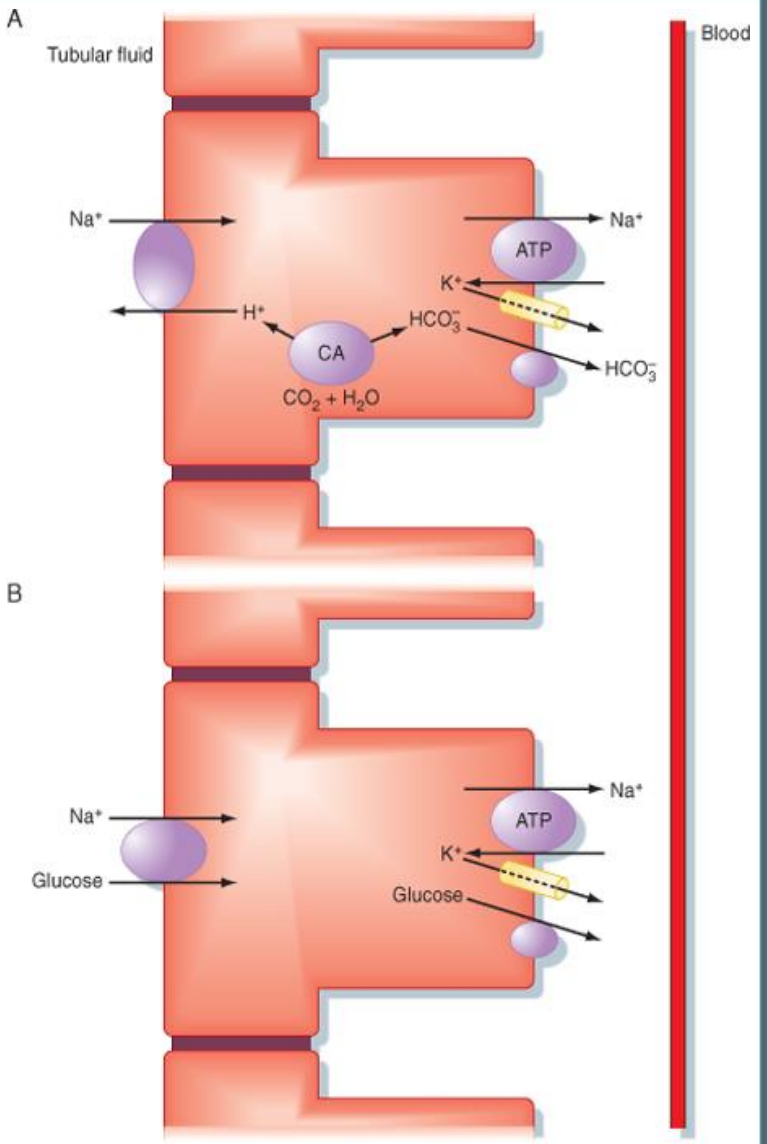
PCT

a) NHE takes up Na^+ for H^+

- Causes reabsorption of HCO3-

b) Symporters:

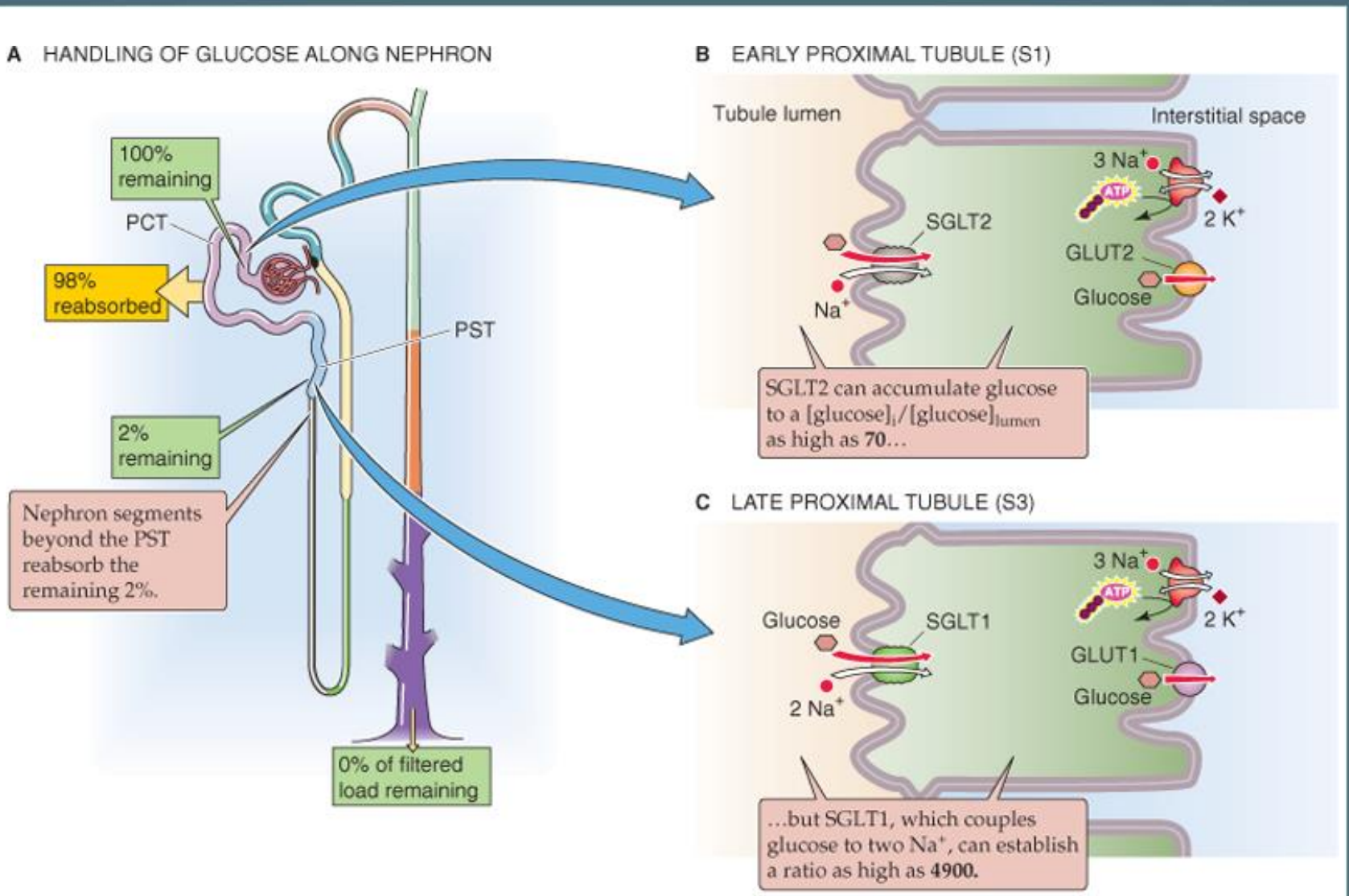
- Na^+-glucose
- Na^+-amino acid
- Na^+-Pi
- Na^+-lactate



Glucose Reabsorption

- From tubular lumen to tubular cell: Sodium co-transporter (Carrier-mediated secondary active transport). Uphill transport of glucose driven by electro-chemical gradient of sodium, which is maintained by Na-K pump presents in basolateral cell membrane.

- From tubular cell to peritubular capillary: Facilitated diffusion (Carrier-mediated passive transport)



Boron & Boulpaep: Medical Physiology, 2nd Edition.

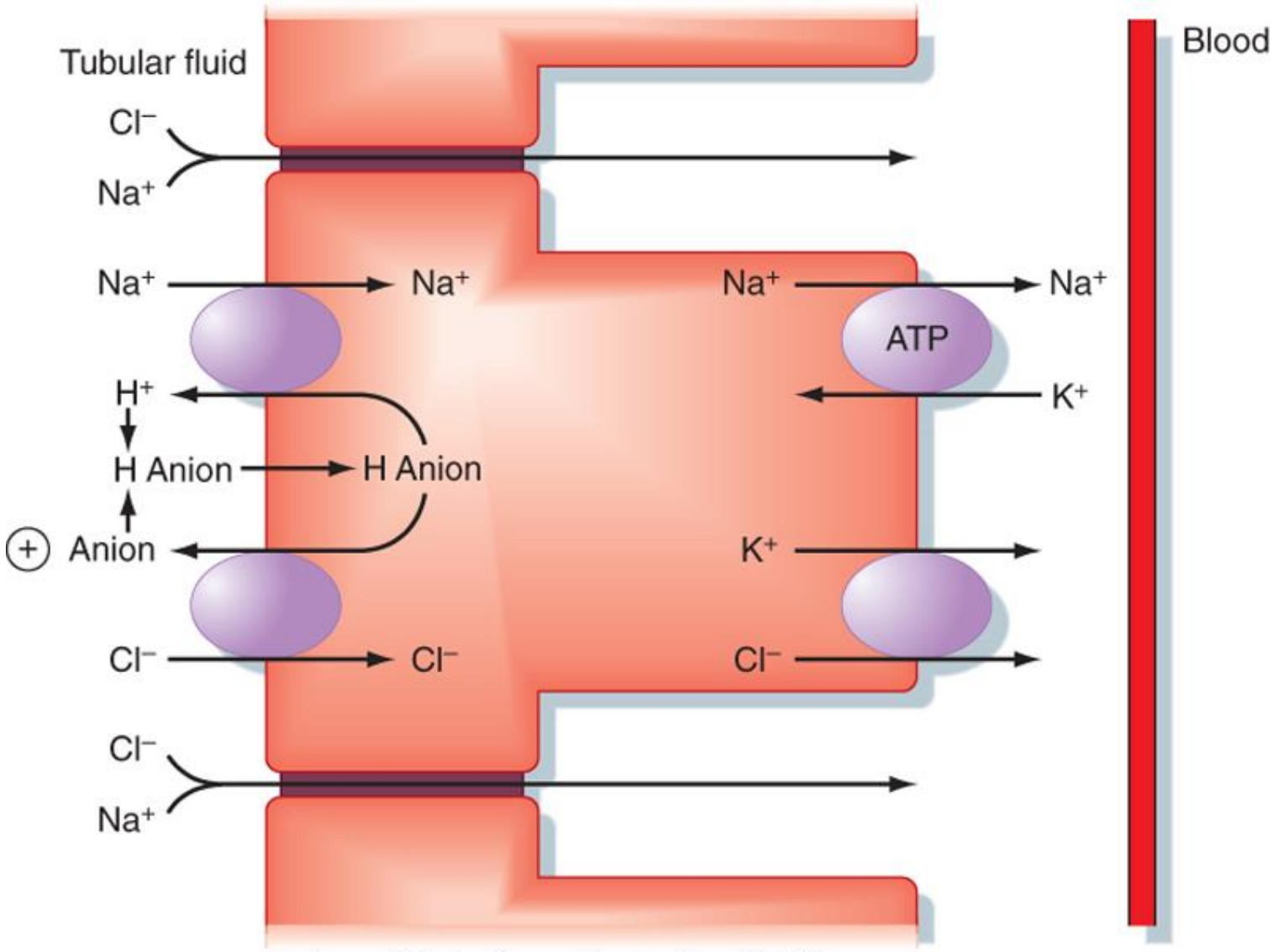
PCT

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

a) Transcellular: Na+ entry using NHE & 1 or 2 Cl^--anion antiporters

- Secreted H^+ & anion combine in the tubular fluid & reenter the cell.

- Anions involved: OH^-, formate, oxalate, sulfate



PCT

b) Paracellular (passive diffusion) With Cl-

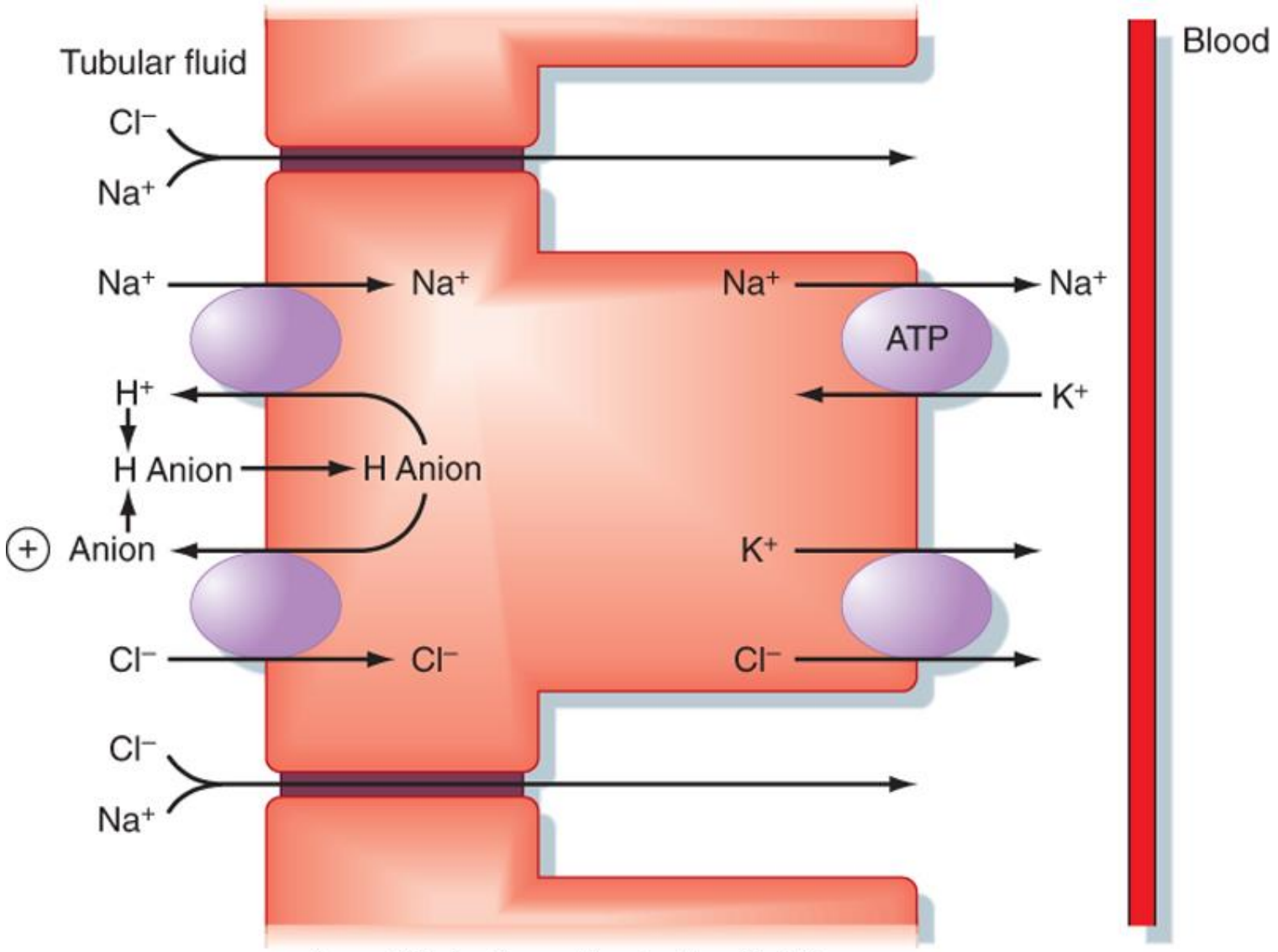
- driven by high [Cl-] in tubule

- 140mEq/L in the tubule lumen and 105 mEq/L in interstitium.

- This conc. gradient favors diffusion of Cl- from the tubular lumen a cross the tight junction into the lateral intercellular space.

  $\Rightarrow$ +ve charge in tubule $\Rightarrow$ Na+ reabsorbed

  1/3 of Na+ reabsorbed this way

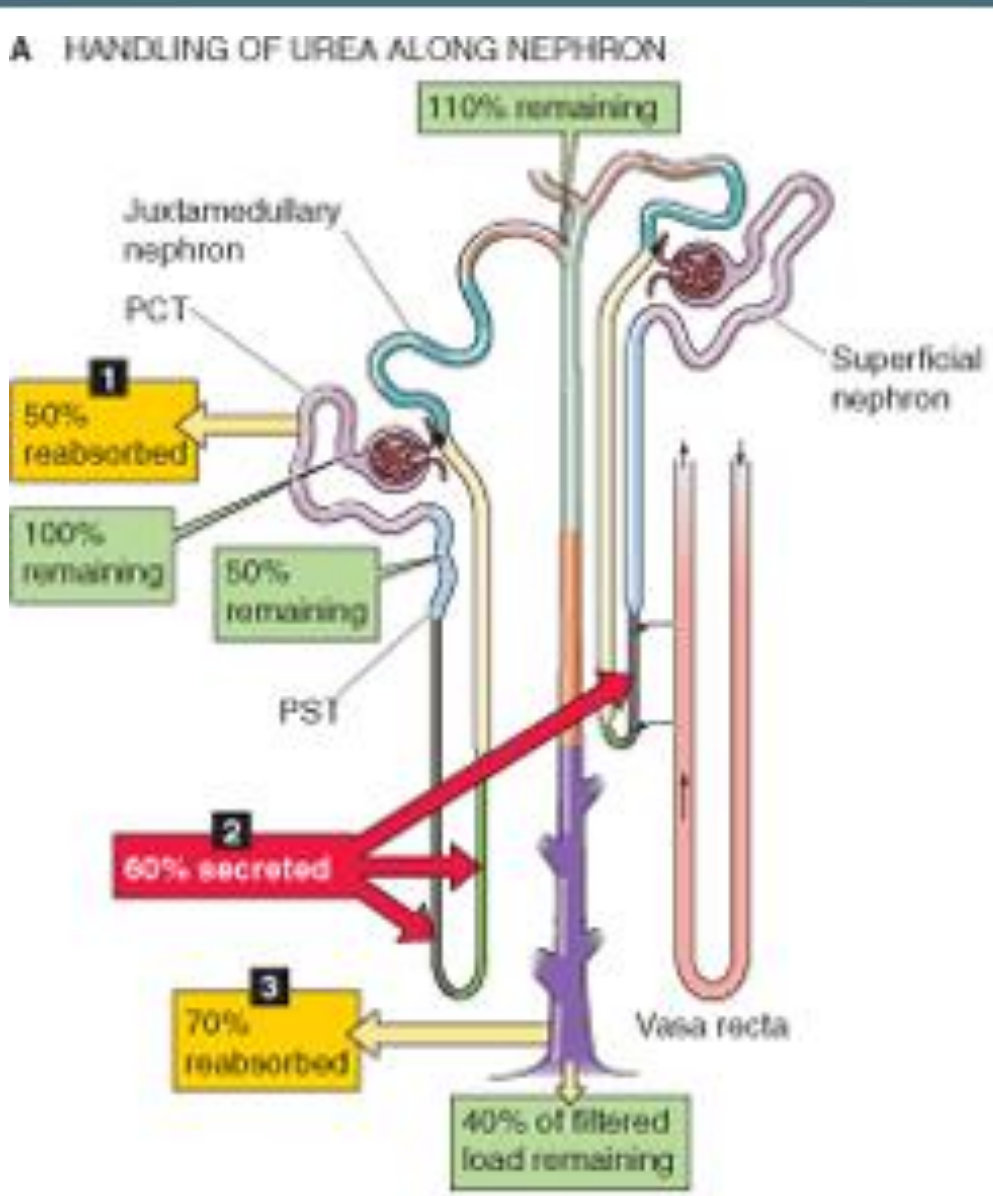


Urea Reabsorption

- 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 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)

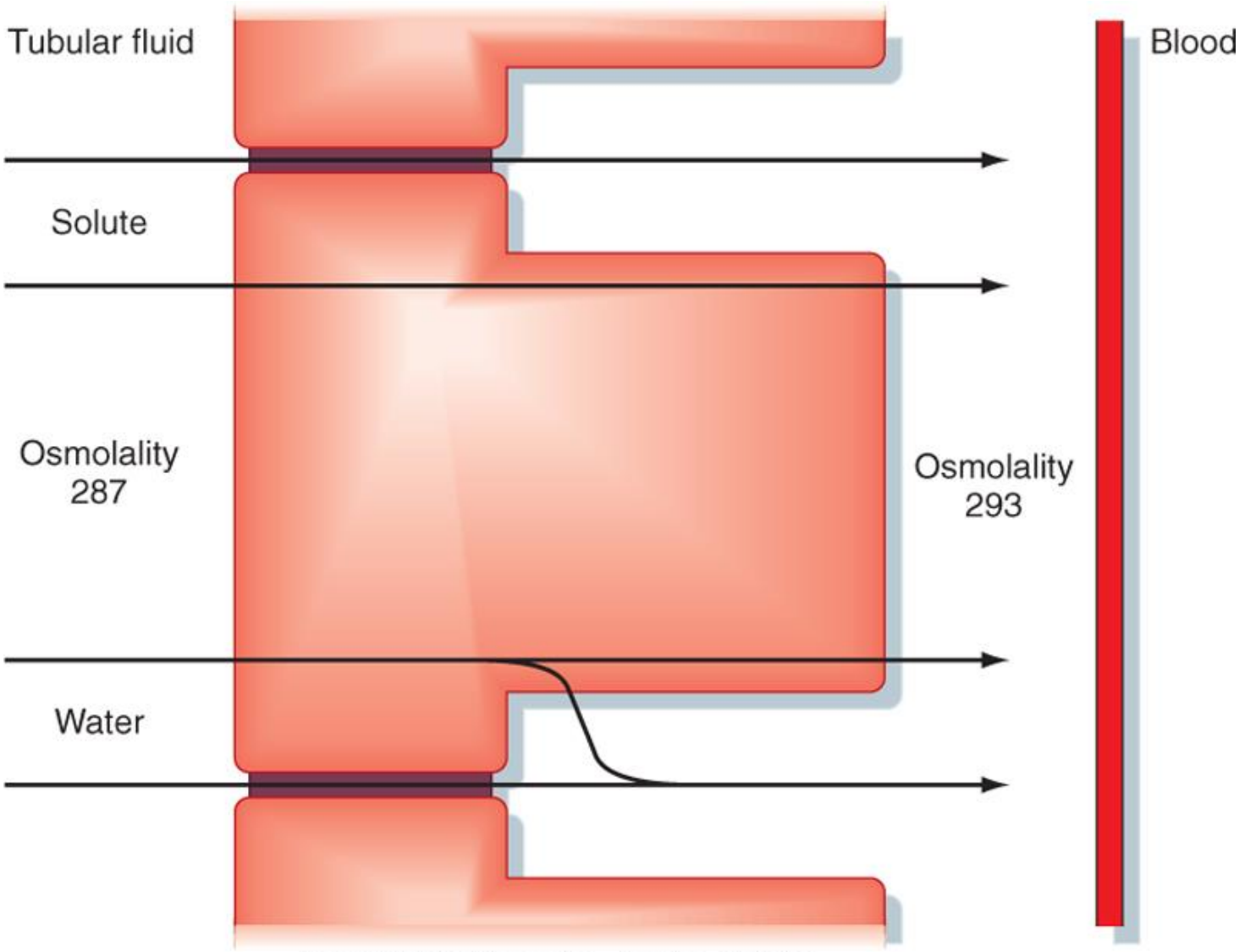

A HANDLING OF UREA ALONG NEPHRON
110% remaining
Juxtamedullary nephron
PCT
Superficial nephron
1
50% reabsorbed
100% remaining
50% remaining
PST
2
60% secreted
3
70% reabsorbed
Vasa recta
40% of filtered load remaining

Water reabsorption

- PCT cells permeable to water
- PCT Reabsorbs 67% of filtered water.
- Transtubular Passive (osmosis), due to osmotic active substances that are absorbed e.g. **Na+**, glucose, HCO3-, Cl-

  $\Rightarrow$ $\downarrow$ tubule osmolality

  $\uparrow$ intracellular space osmolality



Water reabsorption

- Solvent drag: K+, Ca2+, carried with water & hence reabsorbed
- The accumulation of fluid and solutes within the lateral intercellular space increases hydrostatic pressure in this compartment
- The increased hydrostatic pressure forces fluid and solutes into the capillaries. Thus, water reabsorption follows solutes.
- The proximal tubule reabsorption is isosmotic

Protein reabsorption

- Peptide hormones, small proteins & amino acids reabsorbed in PCT
- Undergo Endocytosis into PCT, either intact or after being partially degraded by enzymes.
- Once protein inside the cell, enzyme digest them into amino acids, which leave the cell to blood.
- Has a maximum capacity

  - too much protein filtered = proteinuria

Organic ion/cation secretion

- **Endogenous compounds:**
  - End products of metabolism
  - Bile salts
  - Creatinine
  - Catecholamines (adrenaline, noradrenailne)

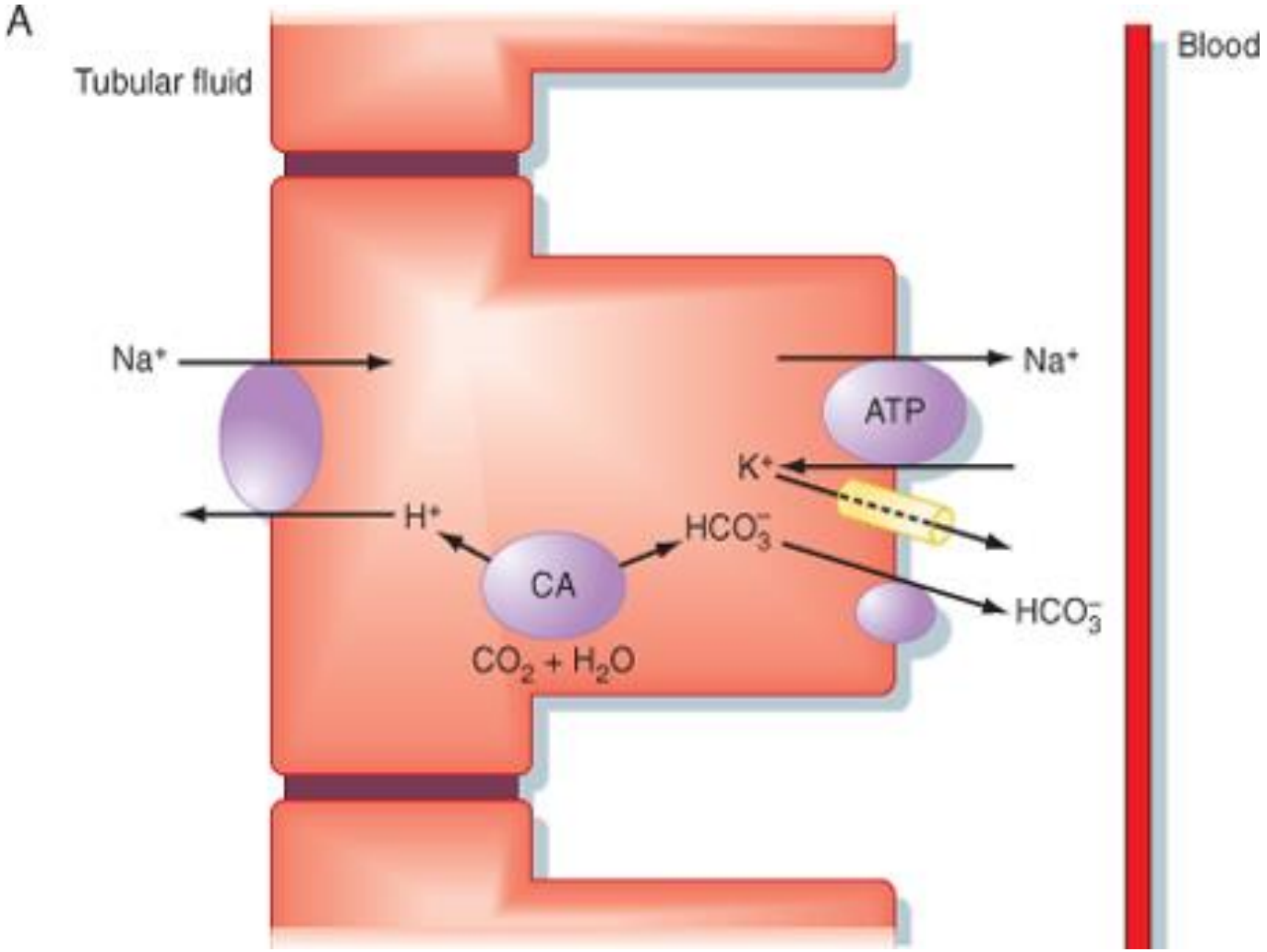
- **Exogenous compounds:**
  - Penicillin
  - NSAIDs (e.g. ibuprofen)
  - Morphine

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^-]