The Anatomy of a Kidney

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Disclosures

- No relevant financial disclosures.

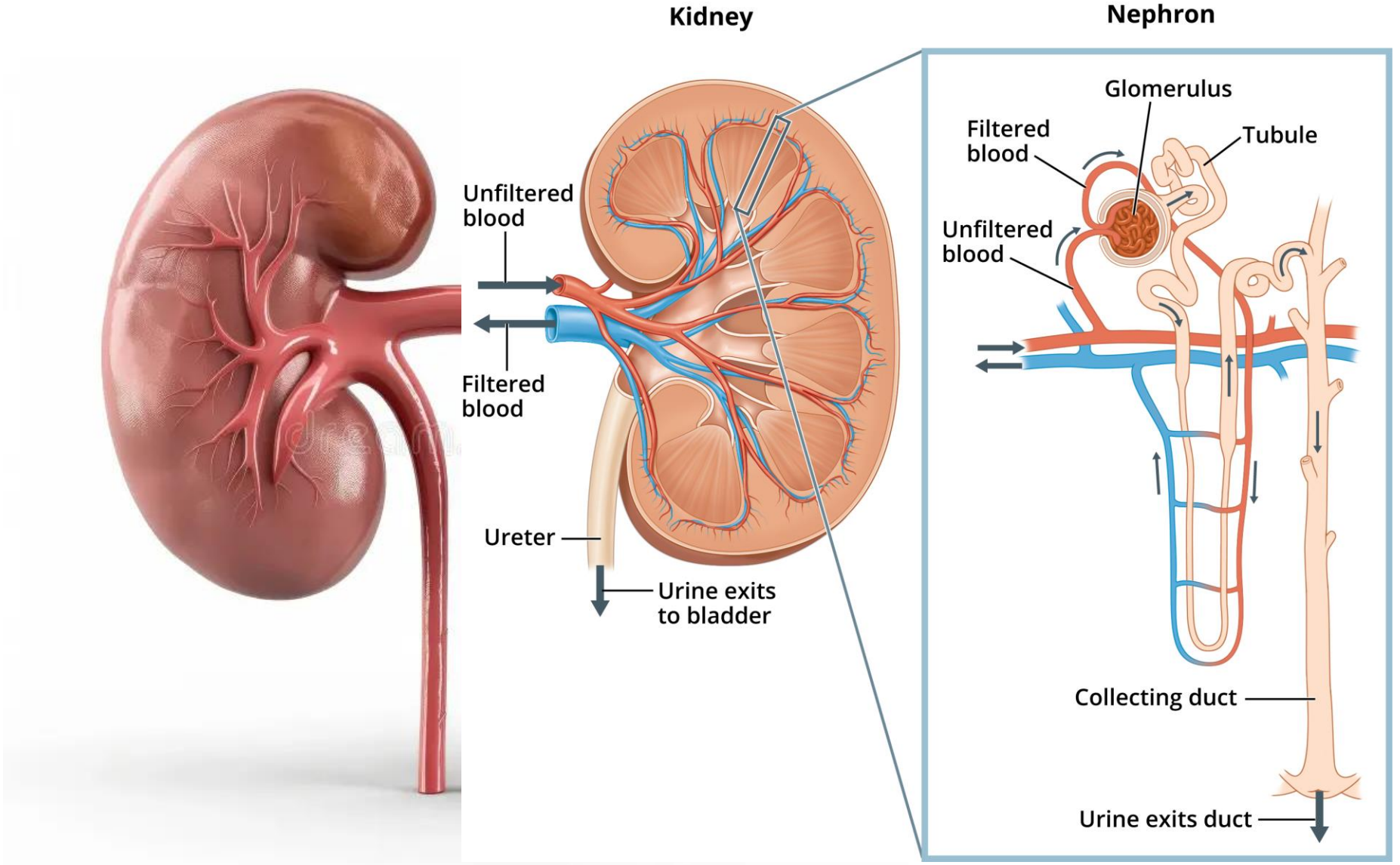
Goals and Objectives

- Describe the main functions of the kidney.
- Describe the properties of the glomerulus - the site of filtration of blood.
- Describe the differences in ion and water transport in each part of the tubule.
- Recognize the changes in homeostasis that occur when there are pathologic changes in the tubule.

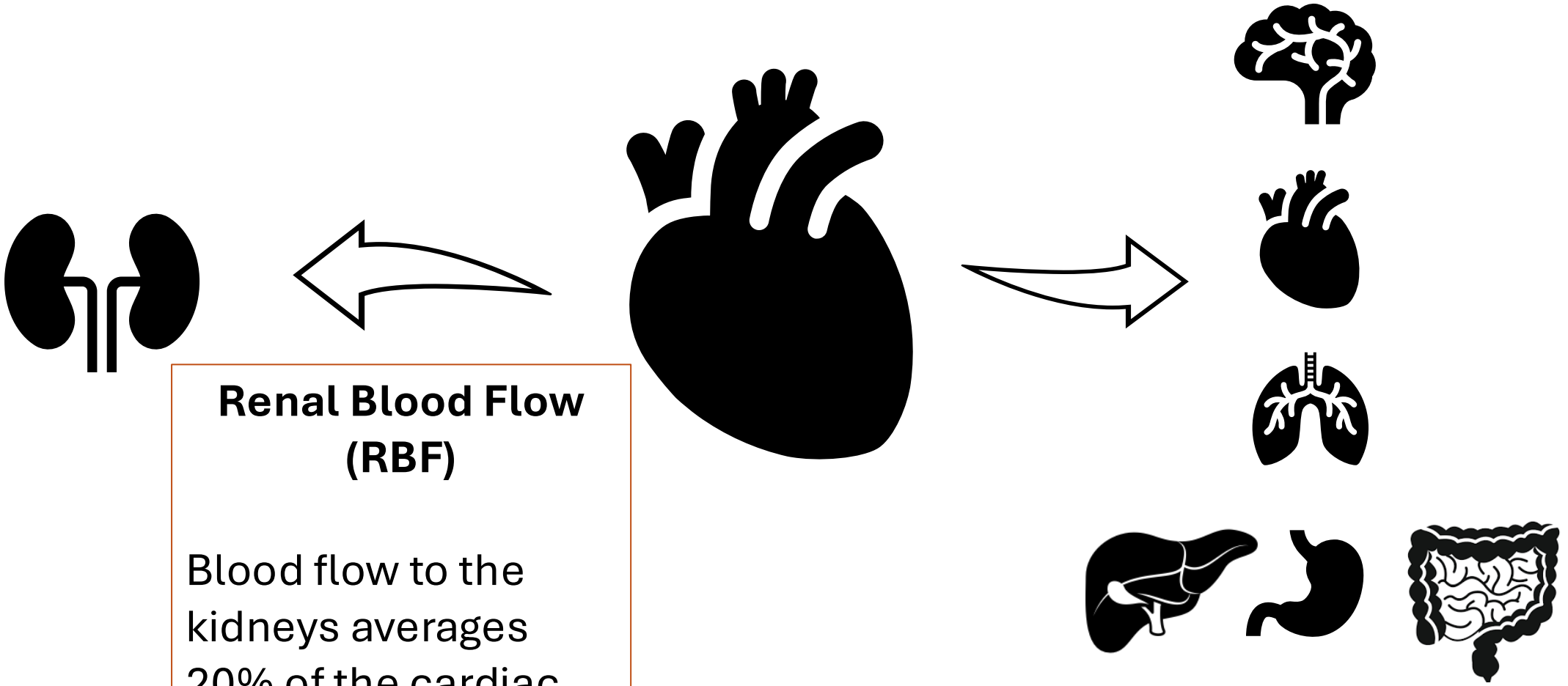
Summary of the Kidney's Functions

- Maintenance of the constant extracellular environment
- Hormone secretion
- Blood pressure regulation

Form Follows Function



Blood Flow to the Kidneys



Renal Blood Flow (RBF)

Blood flow to the kidneys averages 20% of the cardiac output

Why do the kidneys require so much blood flow?

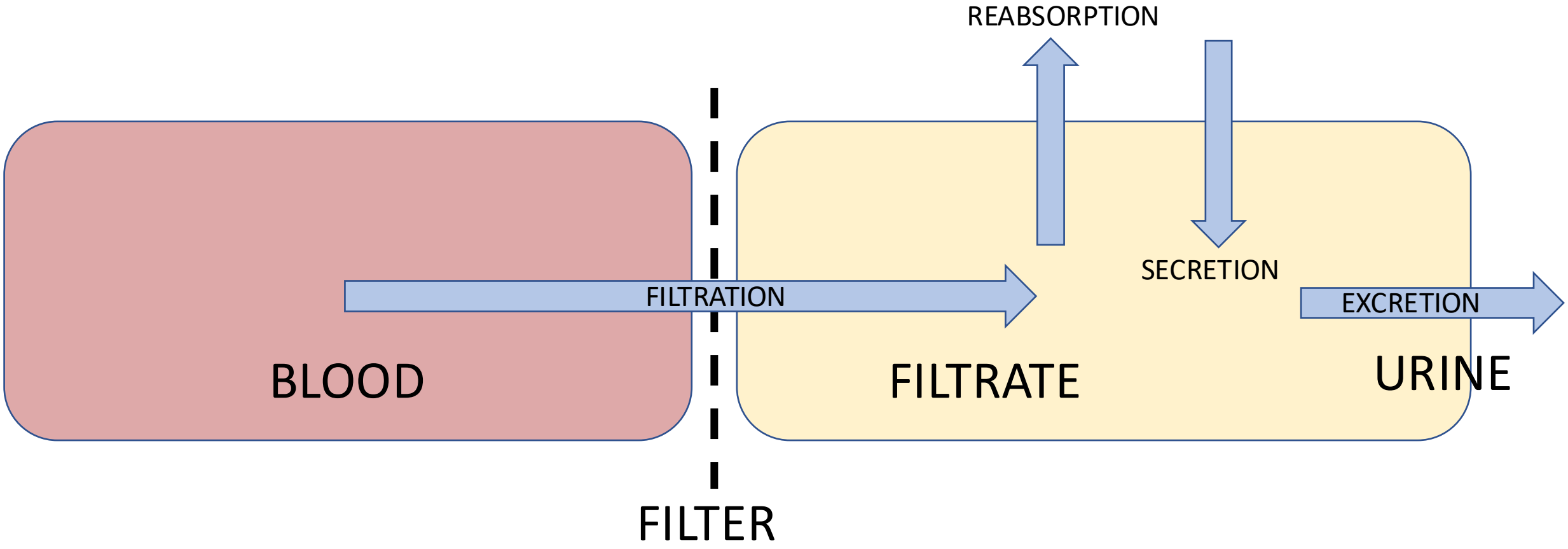
- A constant extracellular environment is required for adequate functioning of cells.

OUTPUT = INTAKE + ENDOGENOUS PRODUCTION

Urine = Water + Electrolytes + Toxins	Diet	Waste products of metabolism (urea, creatinine, uric acid etc)

The Kidney is a Convective Organ

DEFINITION: Convection is movement of molecules through a semipermeable membrane associated with fluid movement ("solvent drag")



Filtration Capacity of the Kidneys

Normal Glomerular Filtration Rate (GFR)

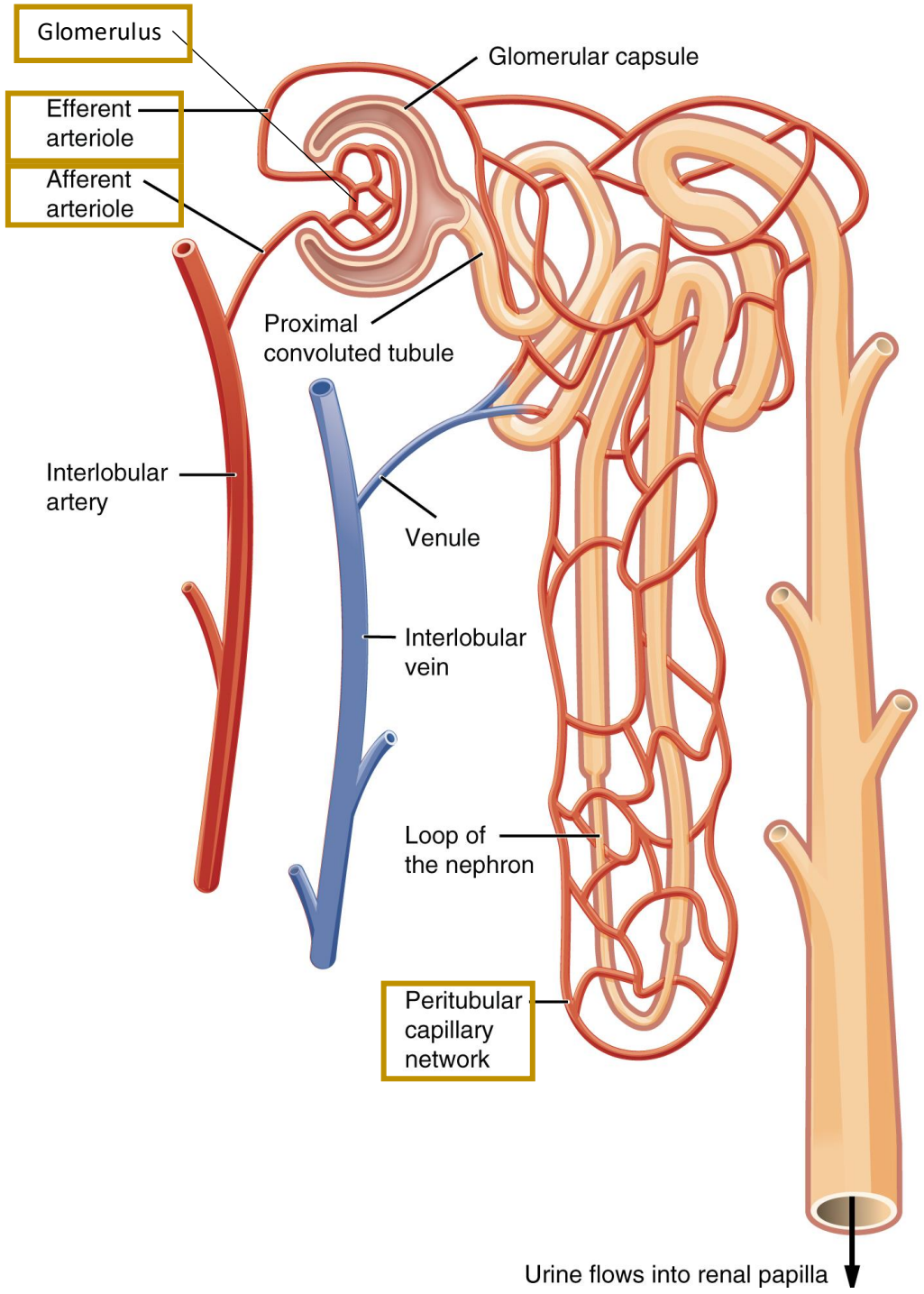
= 125 mL/min/1.73m2

Filtered volume/day

= 125 mL/min/1.73m2 x 60 min/hour x 24 hours

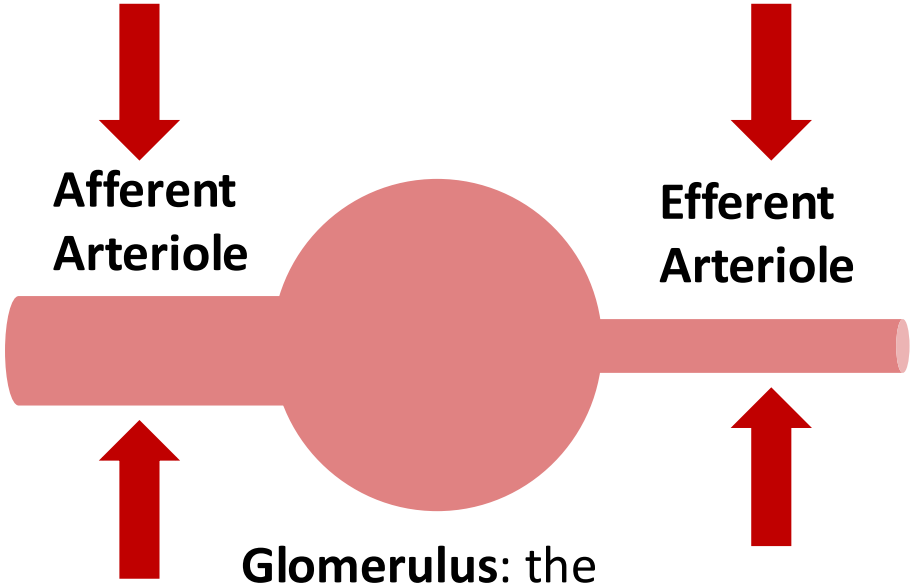
= 180,000 mL/day (180 L/day)

Anatomical Arrangement of Blood Vessels within the Kidney



*The blood side (capillaries) and the urine side (tubules) are separated.

Uniqueness of the Renal Capillary Bed

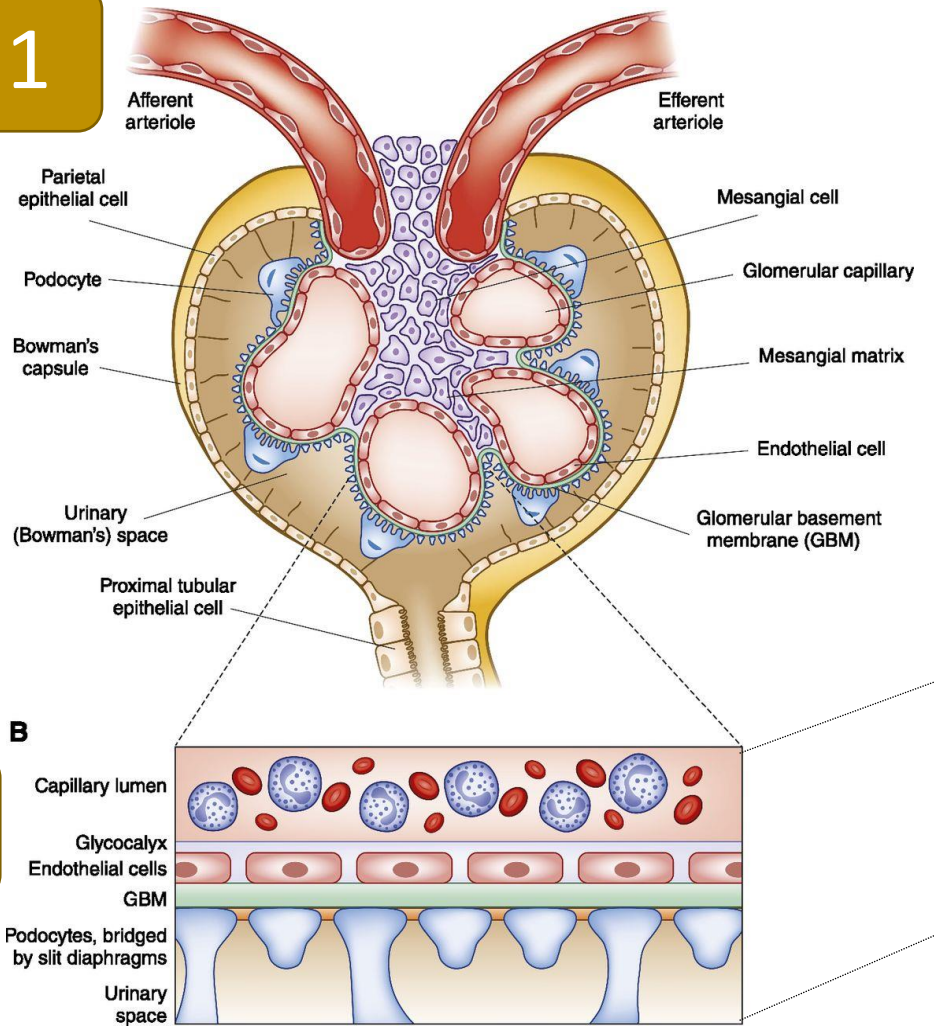


Glomerulus: the organ's capillary bed

The kidney's capillary bed (the glomerulus) is the only capillary bed in the body flanked by 2 resistance vessels.

Anatomy of the Glomerulus

1



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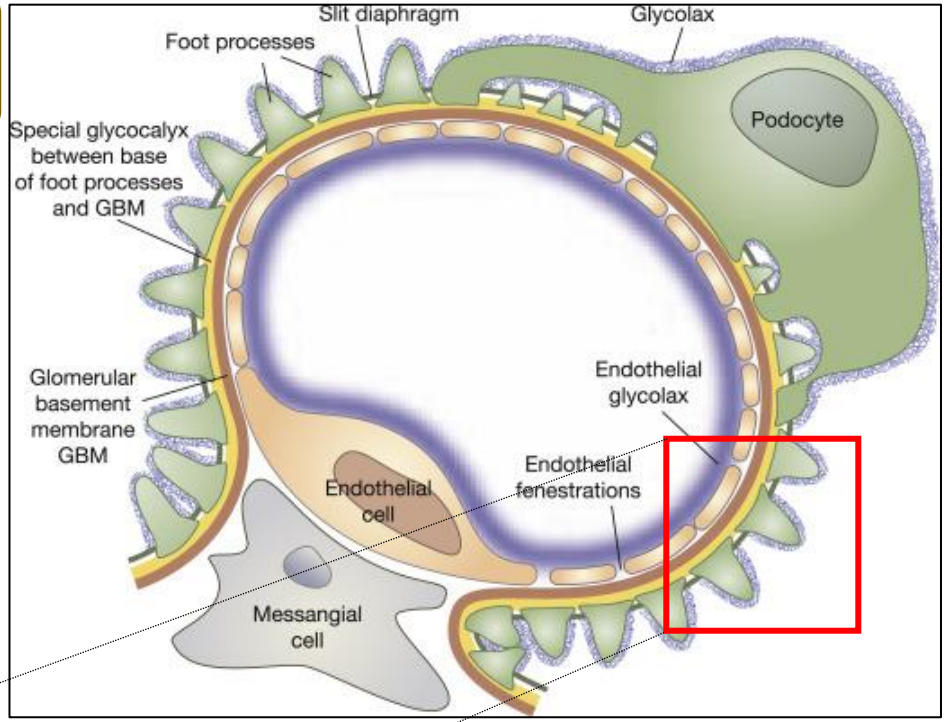

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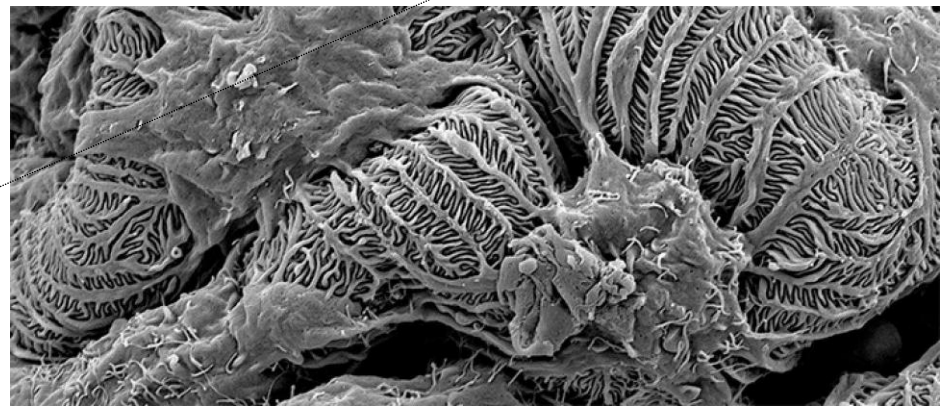
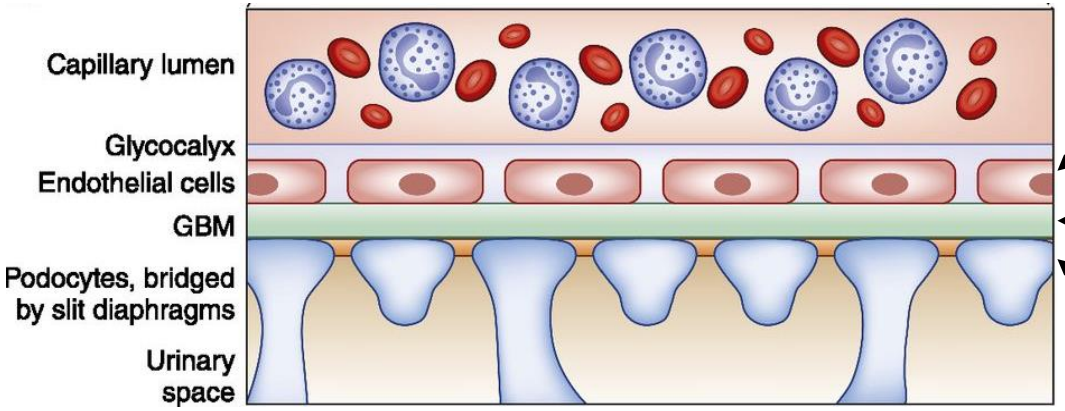


Glomerular Capillary Wall: The Filter

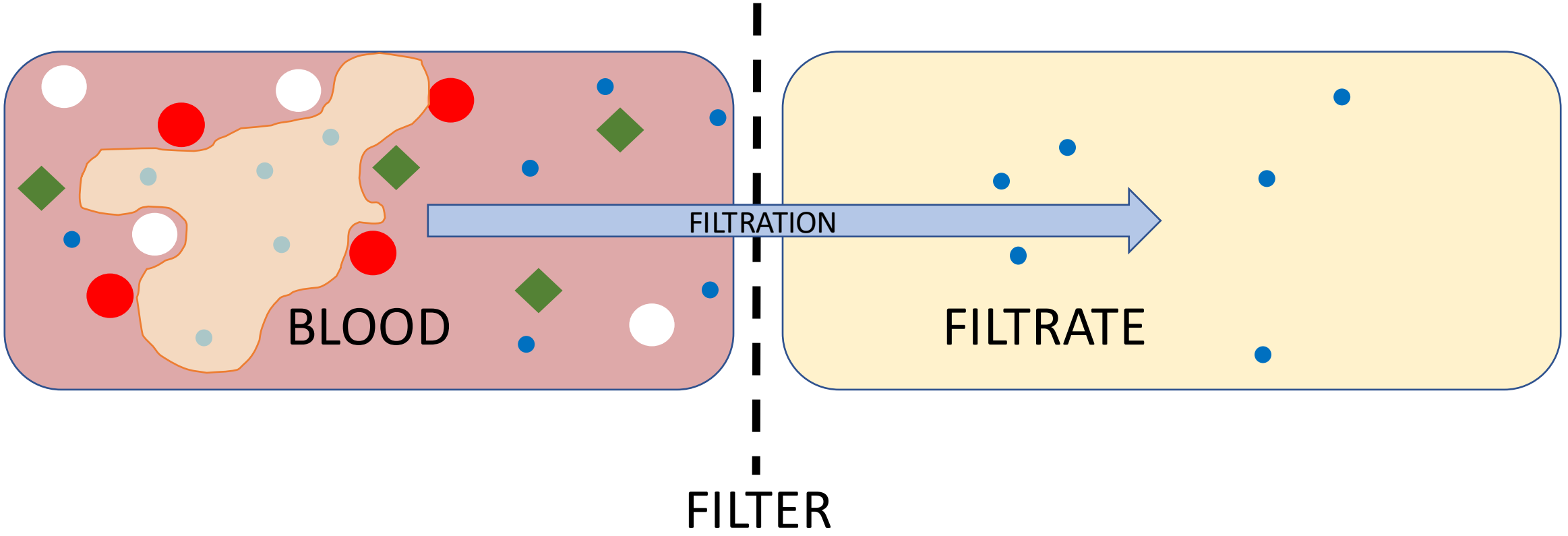


The filter consists of 3 layers resulting in a semi-permeable structure:

1. Fenestrated Endothelium
   - Blood vessel side
   - Covered by glycocalyx
2. Glomerular Basement Membrane (GBM)
   - Made of Type IV collagen
   - Plays a structural and anchoring role
3. Epithelial Cells = Podocytes
   - Urine side
   - Projections called foot processes interact with GBM
   - Space between each foot process is the slit diaphragm

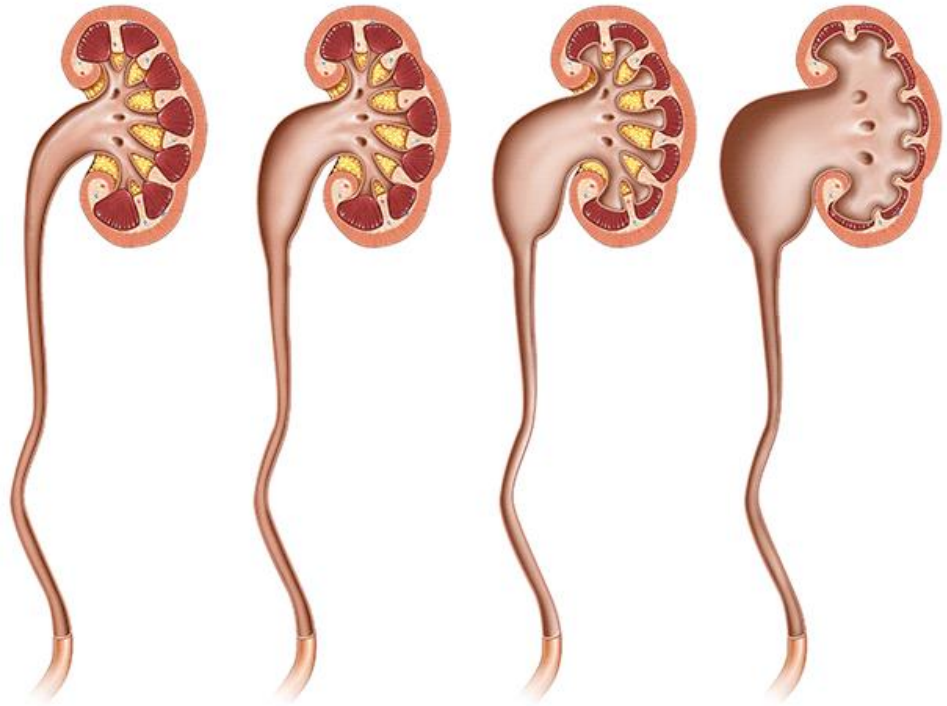
Glomerular Filtration

- The first step in urine formation is the separation of a filtrate of plasma across the glomerular capillary wall



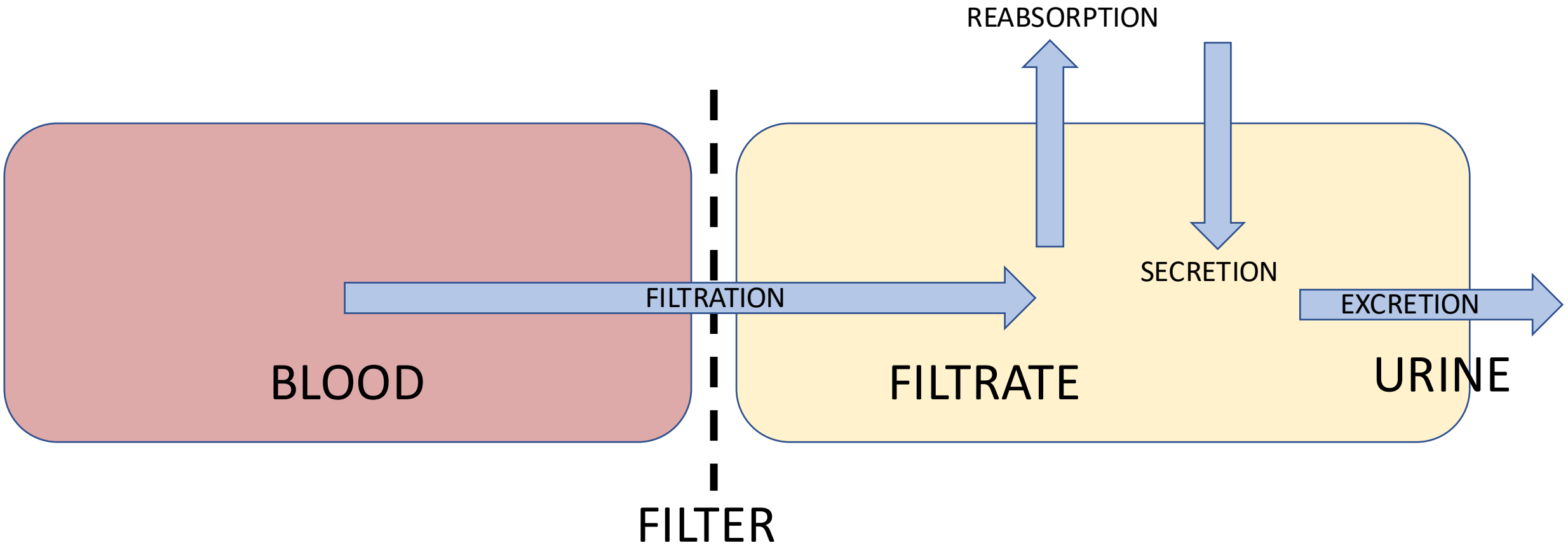
Clinical Case: The Importance of Filtration

- 34+1 week male born with a small, solitary left kidney and severe hydronephrosis
- Managed with an indwelling left nephrostomy tube for 5 months followed by pyeloplasty
- Followed in CKD clinic monthly
- October clinic visit: vomiting, losing weight but eating well, no edema



Clinical Case: The Importance of Filtration

Tubular Function



Tubular Function

Normal GFR = 125 mL/min/1.73m2

Filtered volume/day =

125 mL/min/1.73m2 x 60 min/hour x 24 hours = 180,000 mL/day

Table 1-1 Summary of the net daily reabsorptive work performed by the kidney[a]

Substance	Filtered	Excreted	Percent net reabsorption
Water	180 liters	0.5–3 liters	98–99
Na^+	26,000 meq	100–250 meq	> 99
Cl^-	21,000 meq (598 g)	100–250 meq (2.3-5.8 g)	> 99
HCO_3^-	4800 meq (743 g)	0 (3.5-8.9 g)	~ 100
K^+	800 meq	40–120 meq	85–95[b]
Urea	54 g (31 g)	27–32 g (1.6-4.7 g)	40–50

[a] These values are for a normal adult man on a typical Western diet. The glomerular filtration rate and therefore the filtered load of solutes and water is approximately 25 percent lower in women.

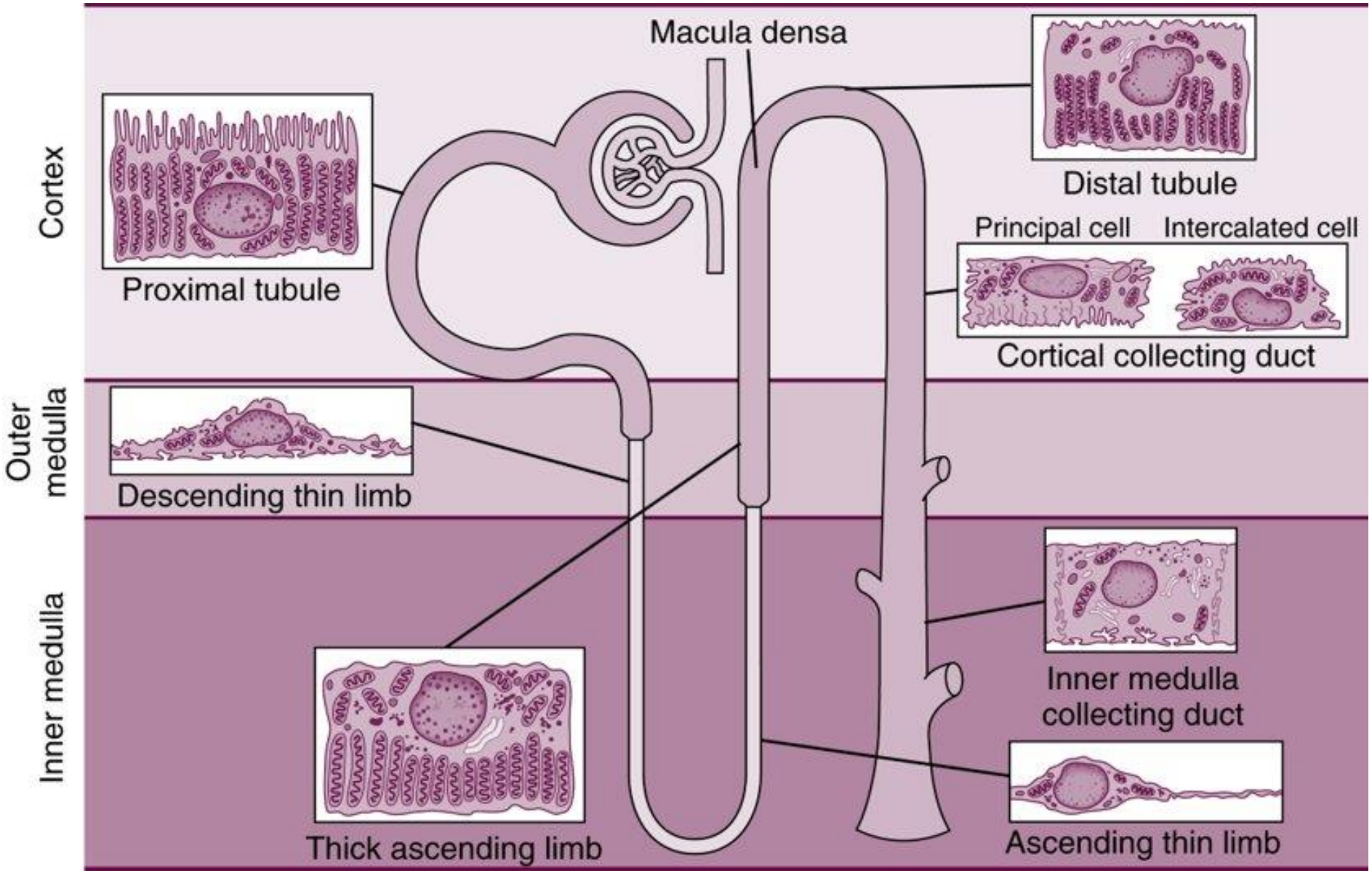
[b] The net reabsorption of K^+ reflects the interplay of two processes: the reabsorption of almost all of the filtered K^+ in the proximal tubule and loop of Henle and the secretion of K^+ into the lumen, primarily in the cortical collecting tubule under the influence of aldosterone. This latter process is the primary determinant of urinary K^+ excretion (see Chap. 12).

Rose, D et al. Clinical Physiology of Acid-Base and Electrolyte Disorders. 5th ed. P10.

Net Result of Filtration, Reabsorption, Secretion and Excretion

The maintenance of a constant extracellular environment for cellular functioning while preserving our precious bodily fluids.

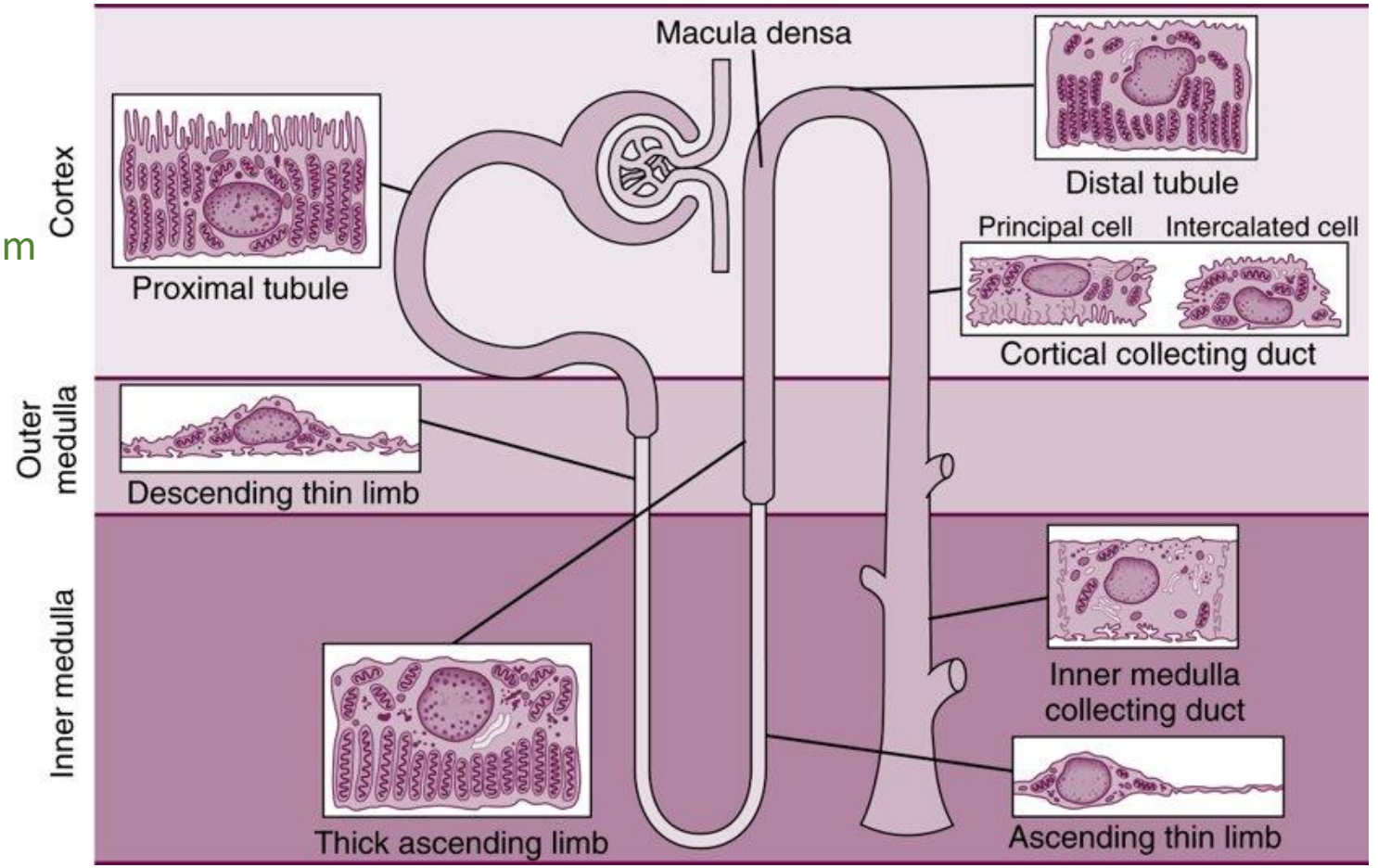
The Nephron


Cortex
Outer medulla
Inner medulla
Macula densa
Proximal tubule
Distal tubule
Principal cell
Intercalated cell
Cortical collecting duct
Descending thin limb
Inner medulla collecting duct
Thick ascending limb
Ascending thin limb

Salt and water reabsorption along the nephron

Proximal tubule
Active and passive reabsorption of sodium
Permeable to water
Reabsorbs 55-60% of filtrate

Thin limb
Passive reabsorption of sodium
Transport of water via AQP1



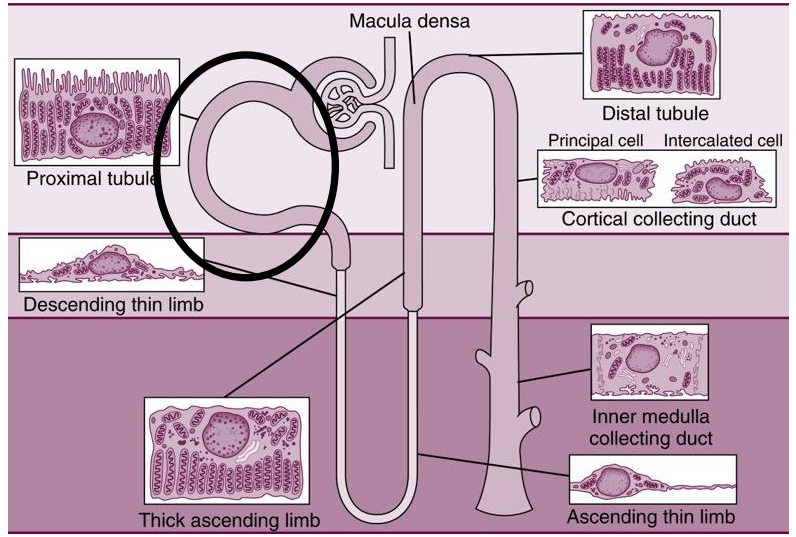
Thick limb
Active transport of sodium
Impermeable to water
Reabsorbs 25-35% of filtrate

Distal tubule
Active transport of sodium
Permeable to water
Reabsorbs 5-10% of filtrate

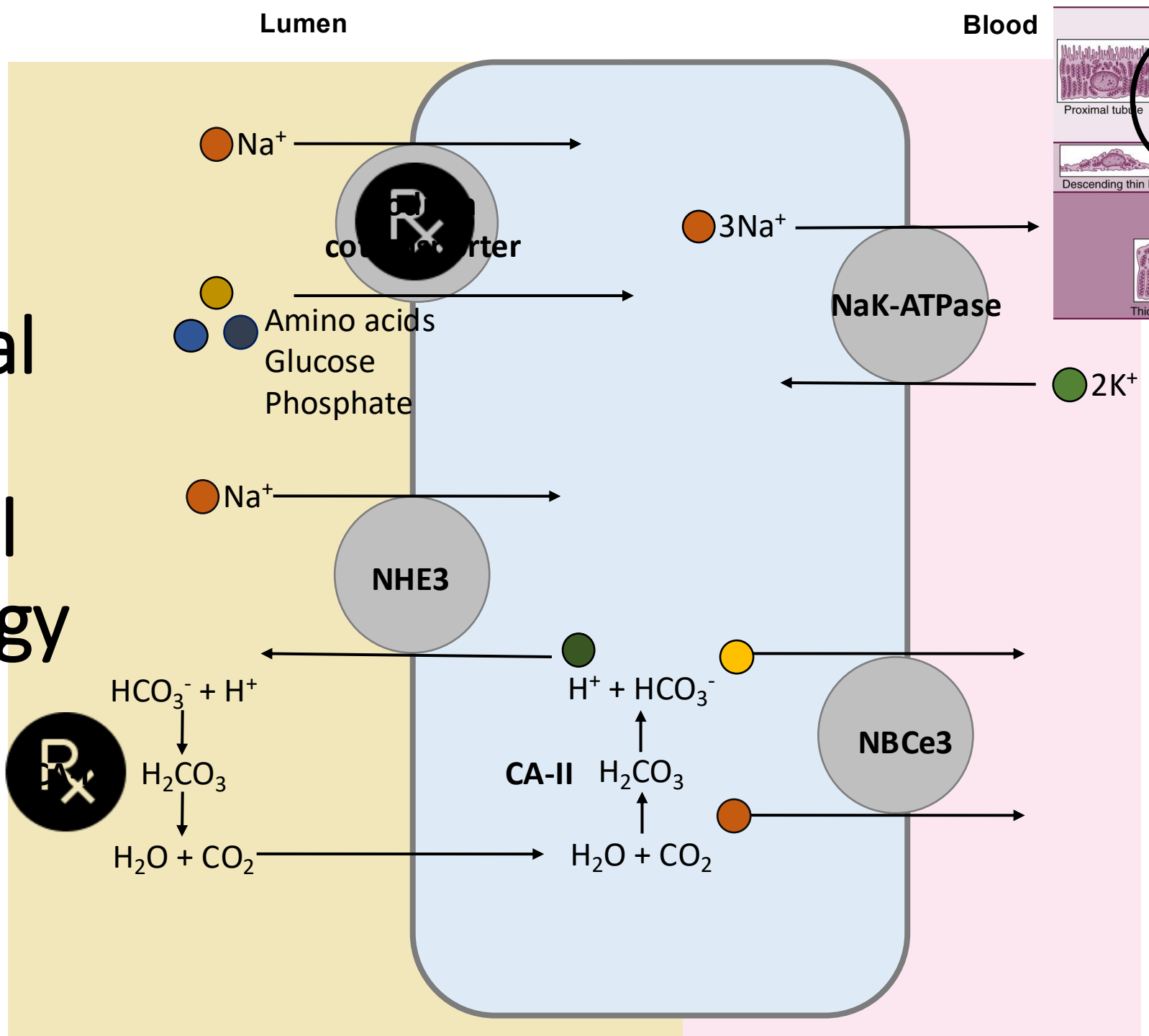
Collecting duct
Active transport of sodium
Transport of water via AQP2
Reabsorbs 5-10% of filtrate

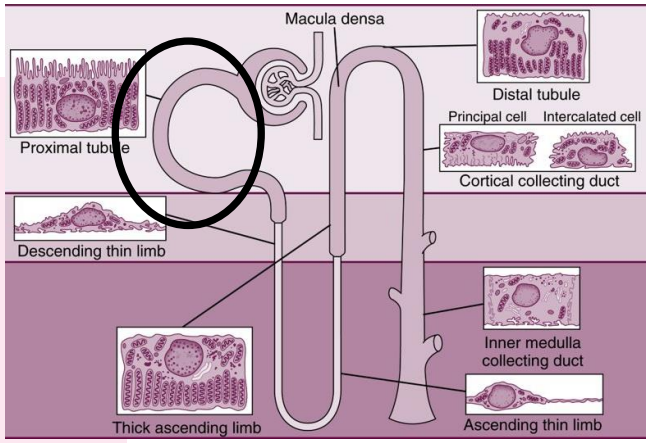
Functions of the Proximal Tubule

- Reabsorption of the majority of salt and water
- Reabsorption of bicarbonate
- Reabsorption of glucose and amino acids

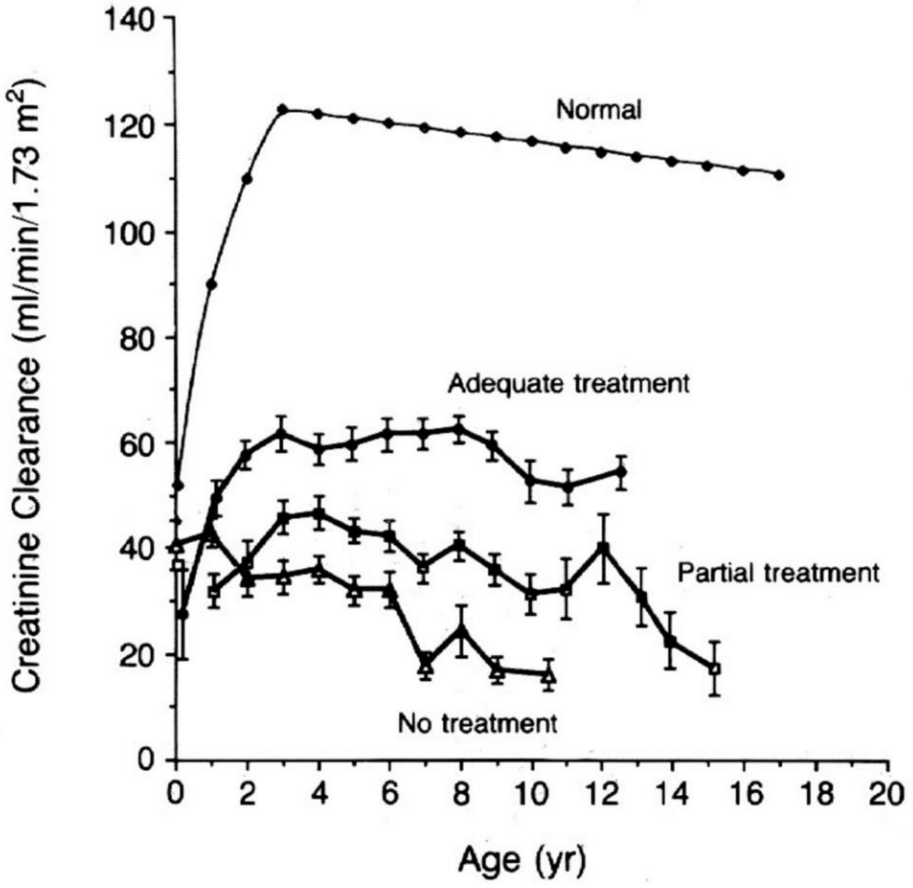


Proximal Tubule Normal Physiology





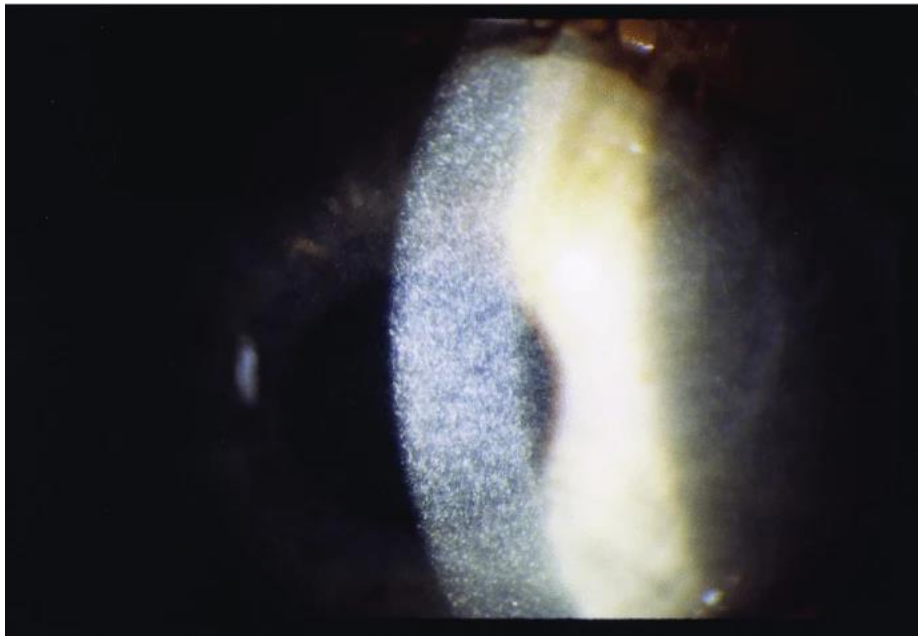
Fanconi Syndrome

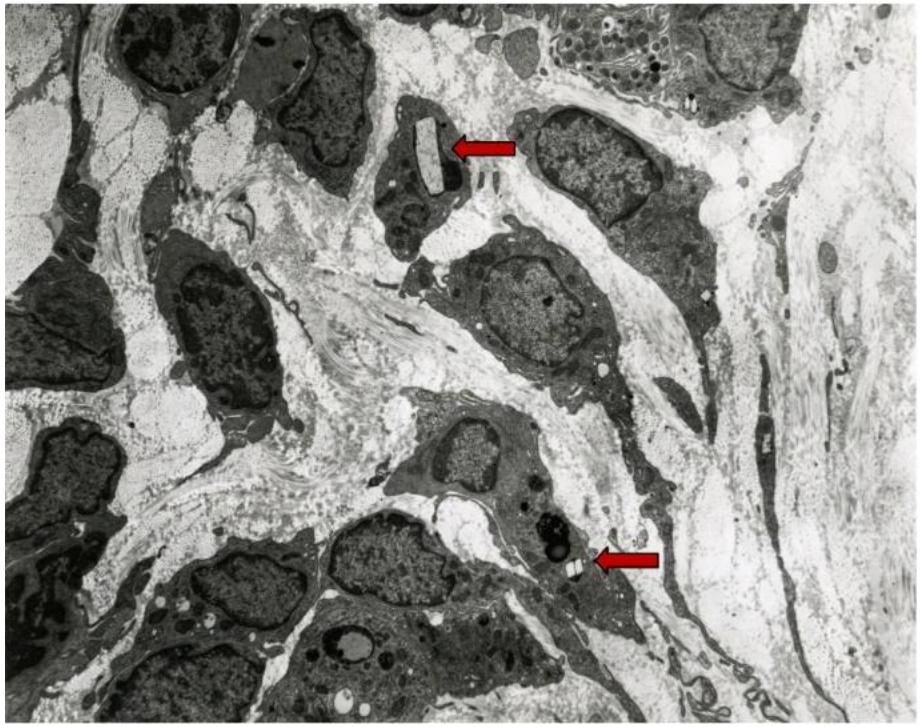


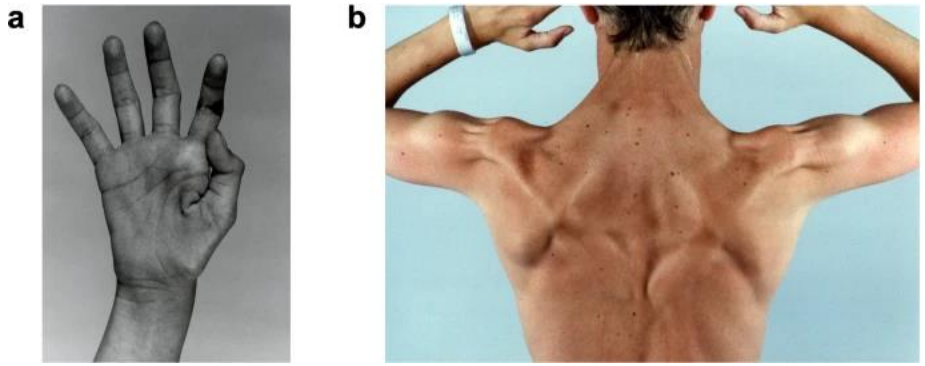
a

b

Fanconi Syndrome

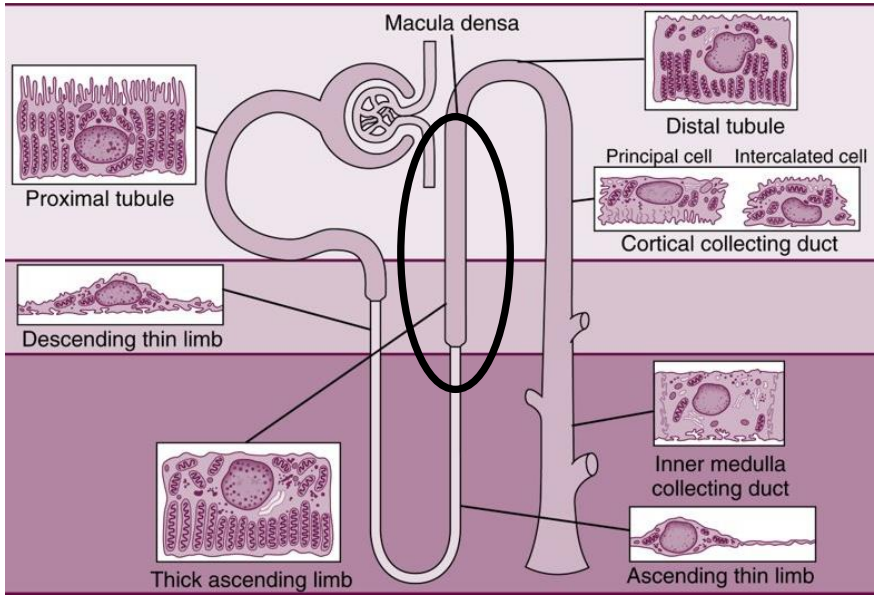




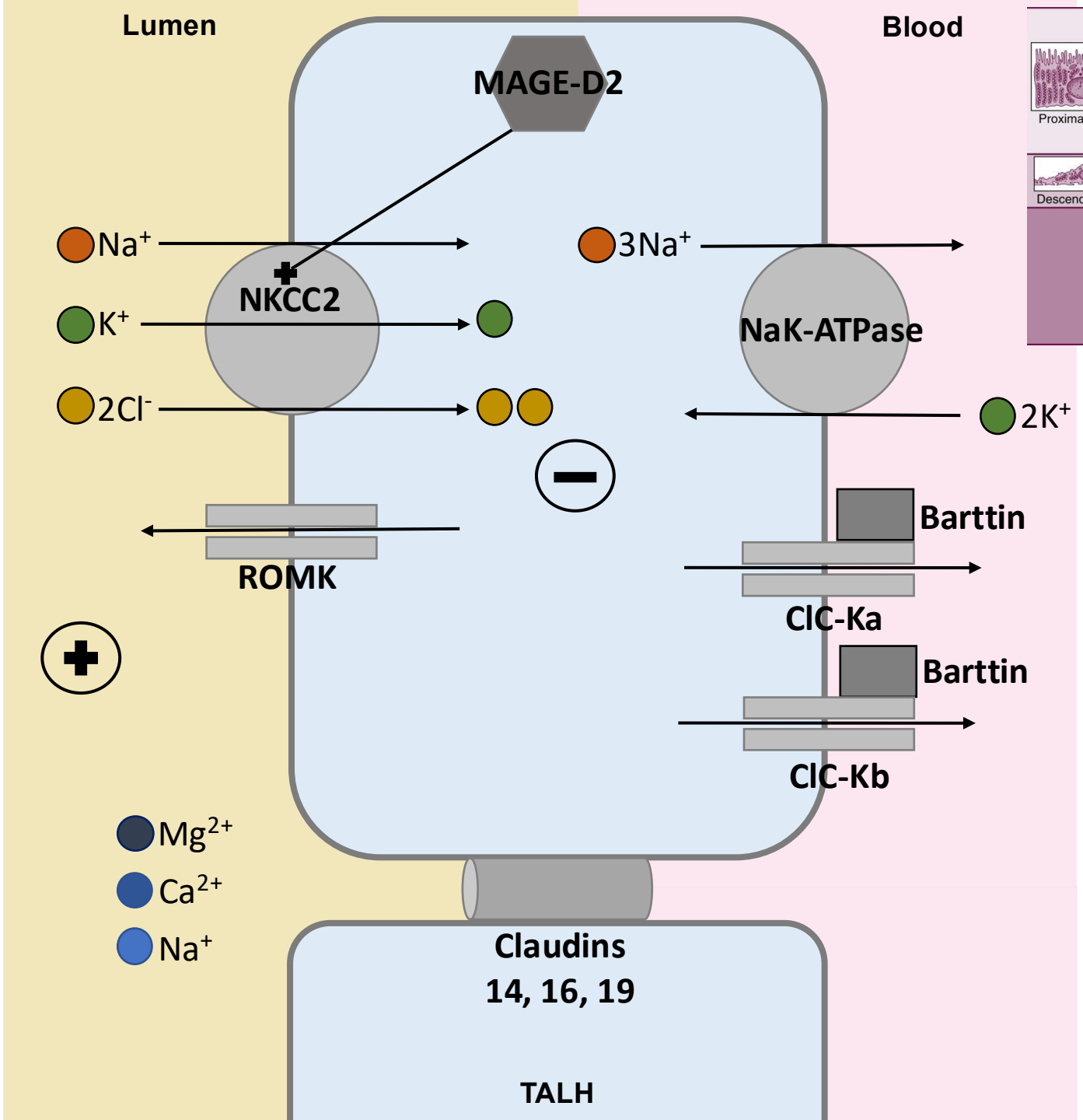


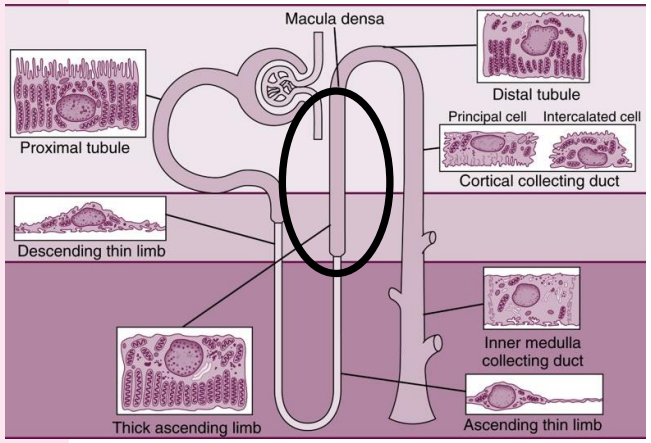
Functions of the TALH

- Diluting segment (dilution of urine)
- Generation of the interstitial concentration gradient
- Salt reabsorption
- Calcium and magnesium reabsorption
  - Reabsorbs ~20% of filtered calcium
  - Reabsorbs ~60% of filtered magnesium



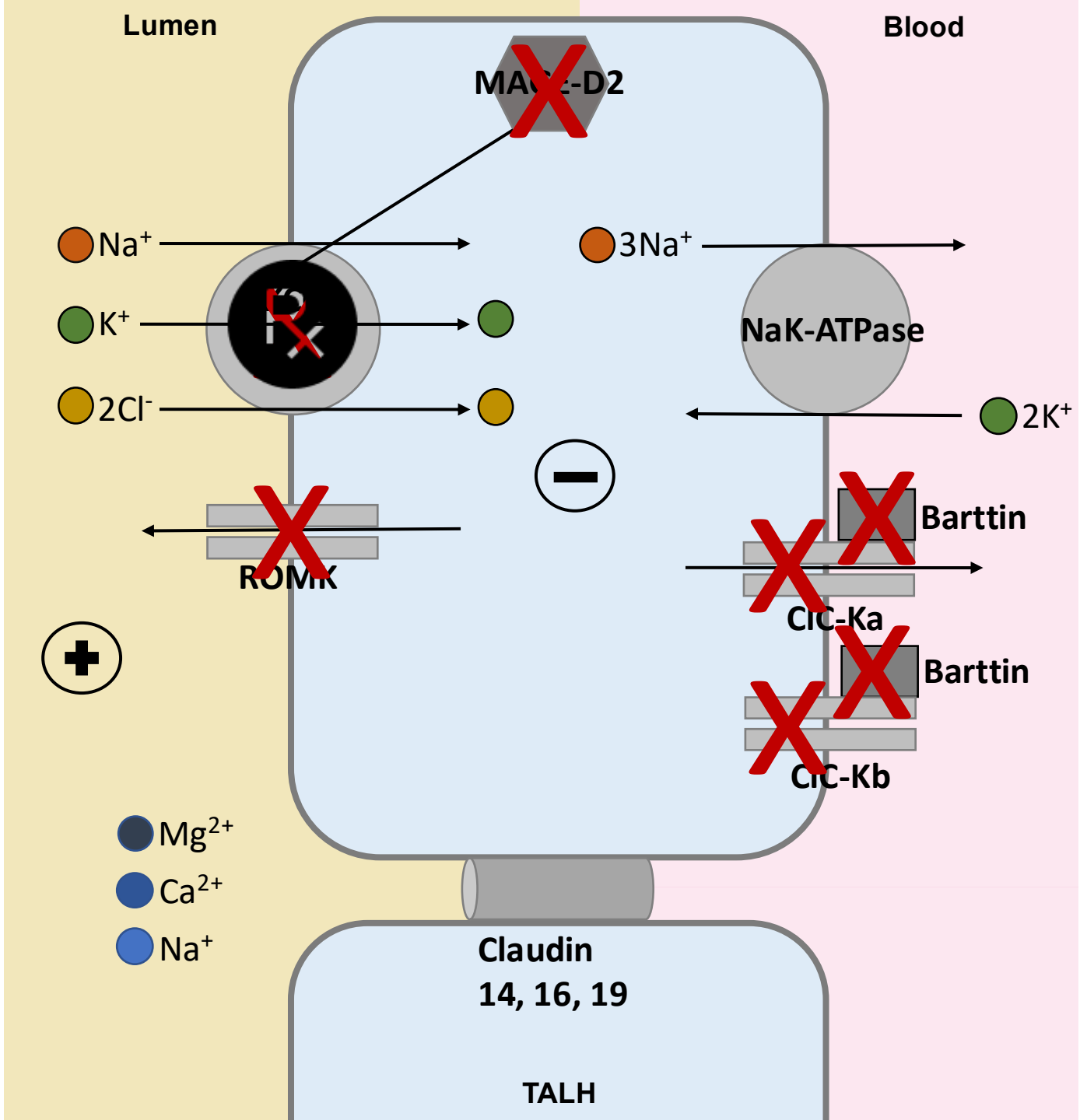
TALH Normal Physiology





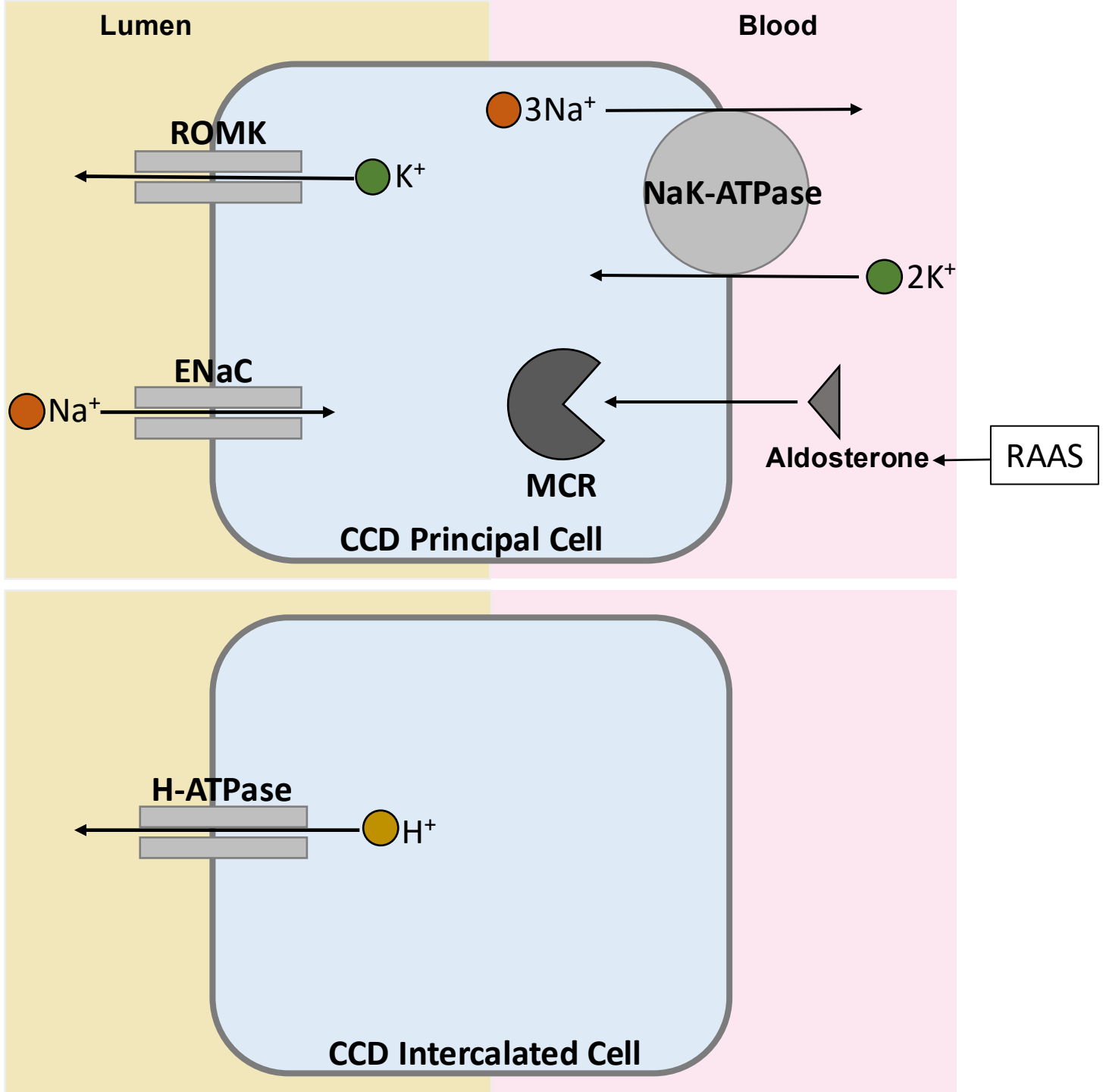
Bartter Syndrome Pathophysiology

- Hyponatremia
- Hypokalemia
- Hypochloremia
- Hypomagnesemia
- Hypercalciuria



Bartter Syndrome Pathophysiology

Hyperaldosteronism
Alkalosis

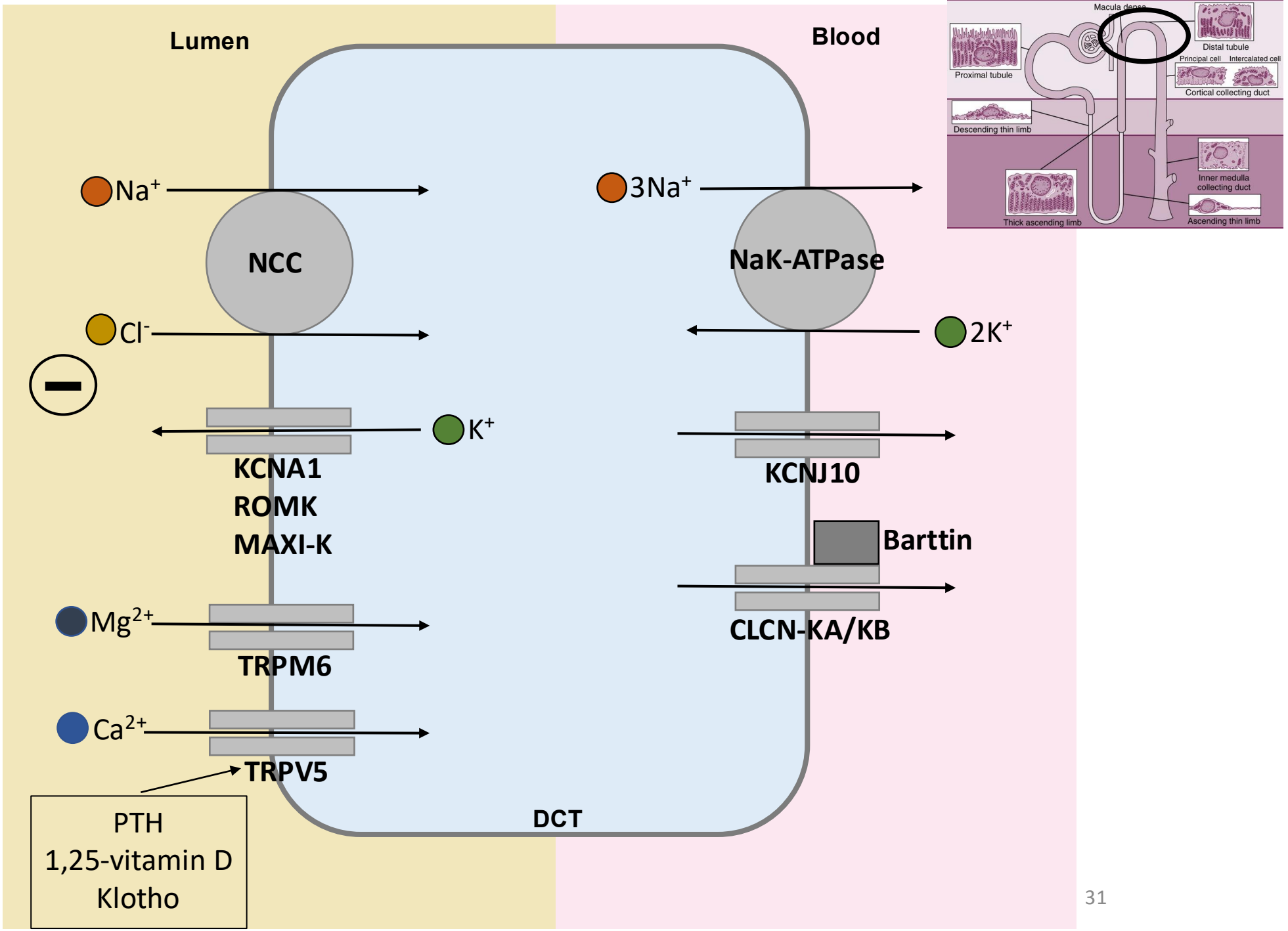


Functions of the Distal Convoluted Tubule (DCT)

- Salt reabsorption

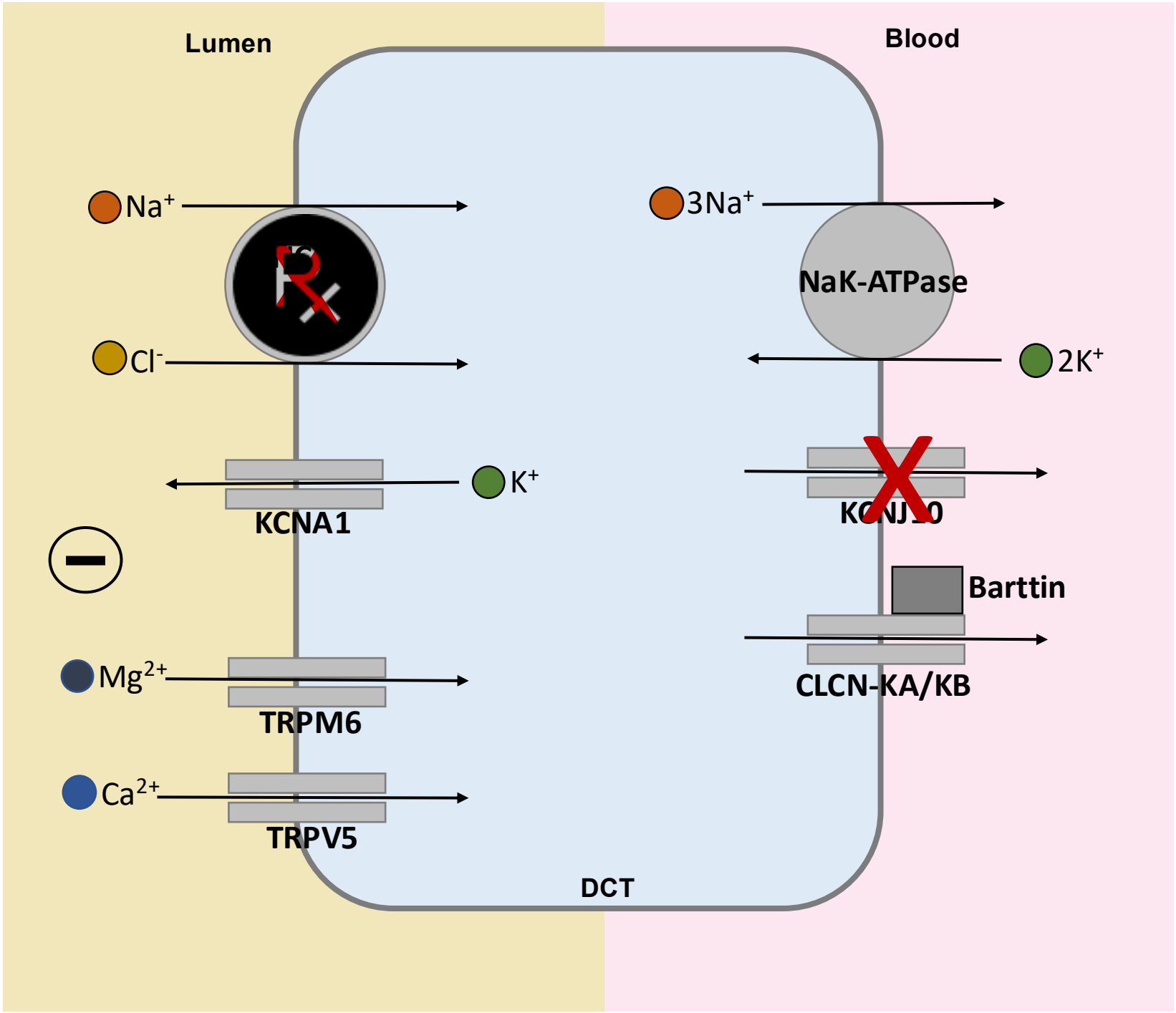
- Calcium and magnesium reabsorption
  - Reabsorbs ~7-10% of filtered calcium
  - Reabsorbs ~10% of filtered magnesium

DCT Normal Physiology



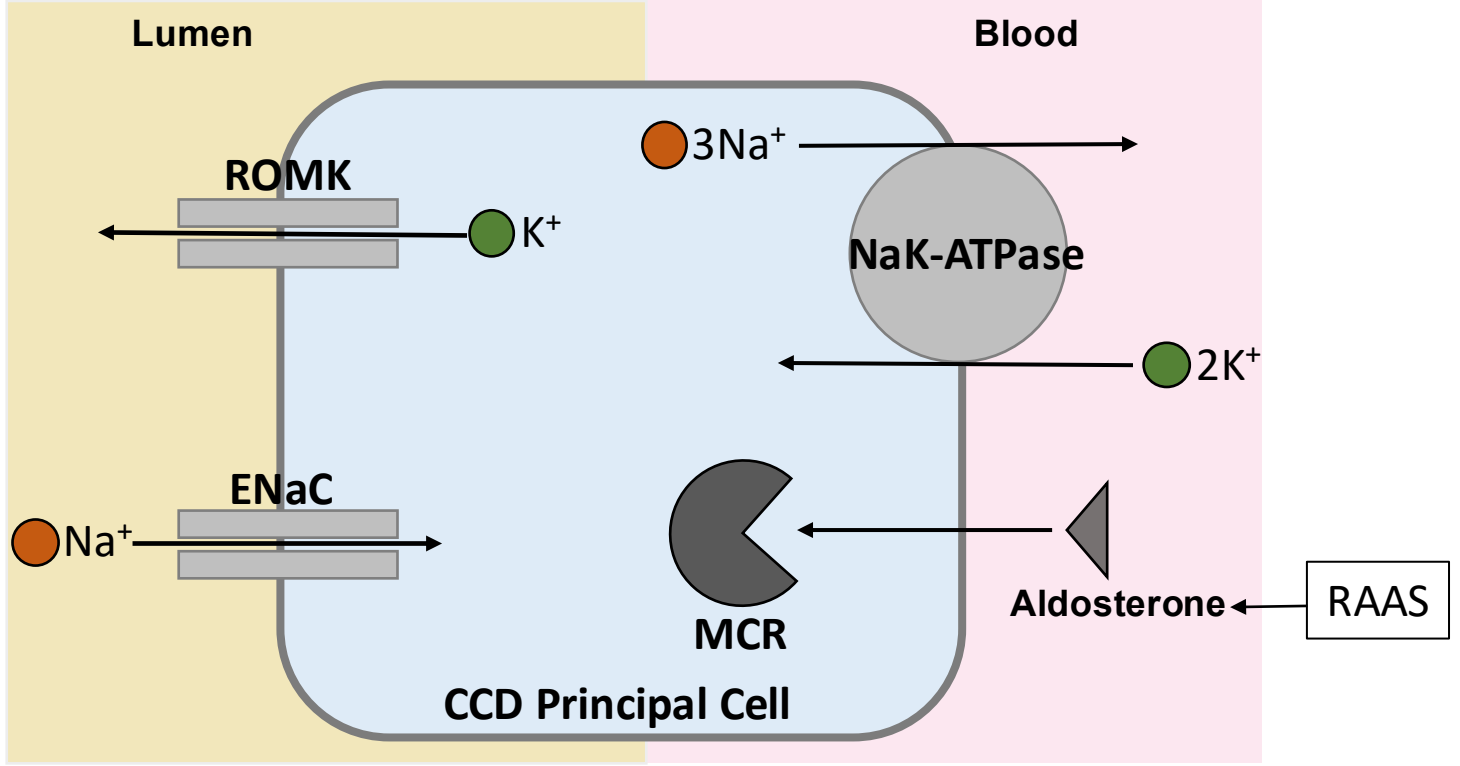
Gitelman Pathophysiology

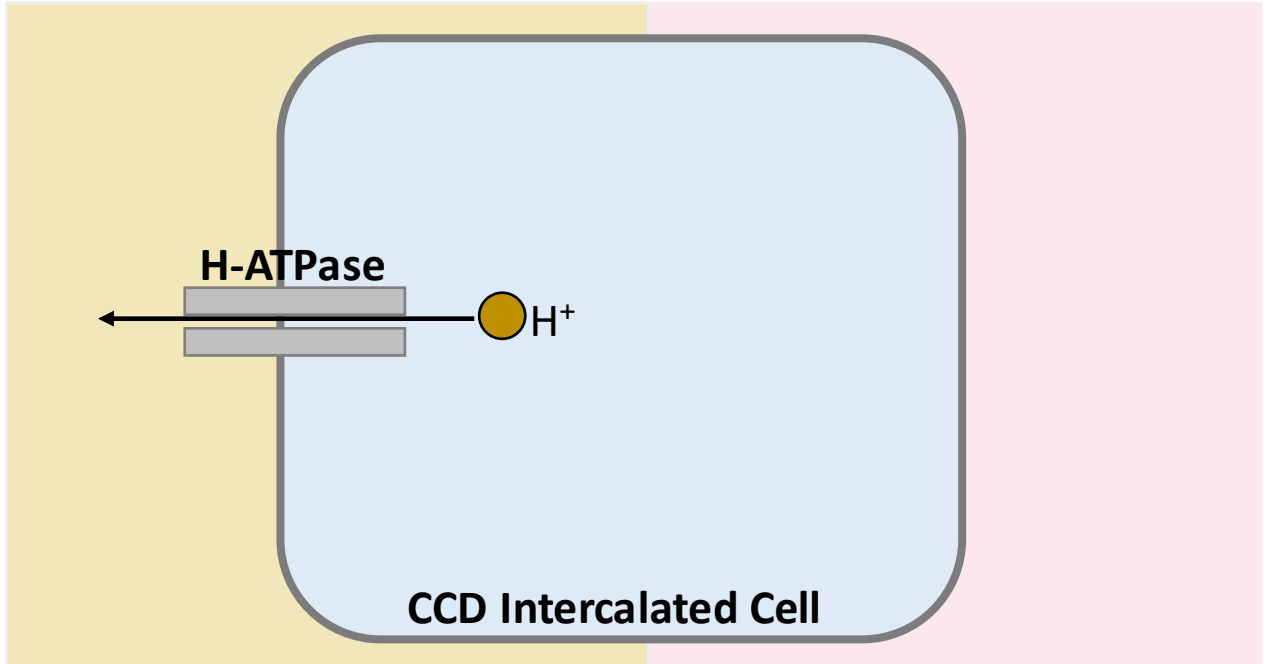
Hyponatremia
Hypochloremia
Hypomagnesemia
Hypocalciuria



Gitelman Pathophysiology

Hyperaldosteronism
Alkalosis



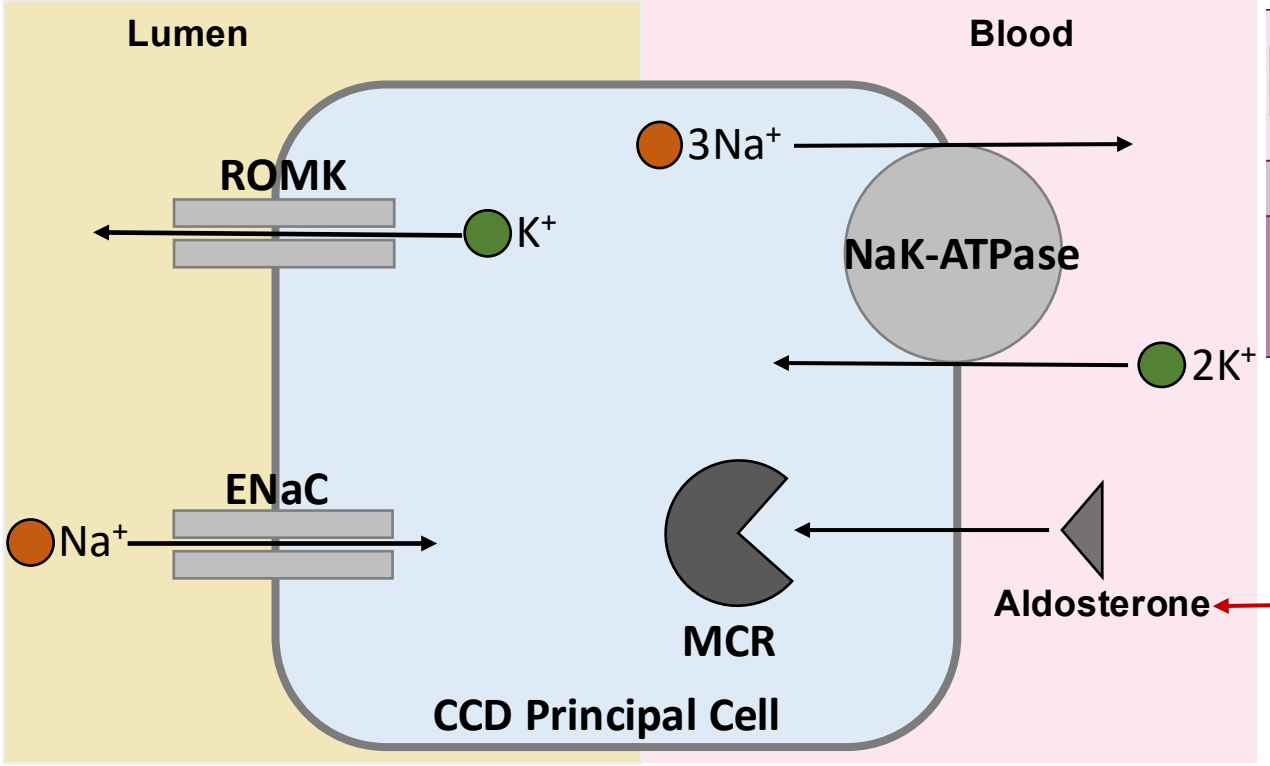


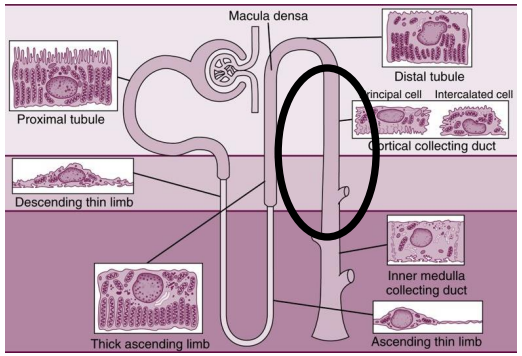
Functions of the Collecting Duct (CD)

- Fine tuning of the urine to ensure that urinary excretion of electrolytes and water matches dietary intake of electrolytes and water.

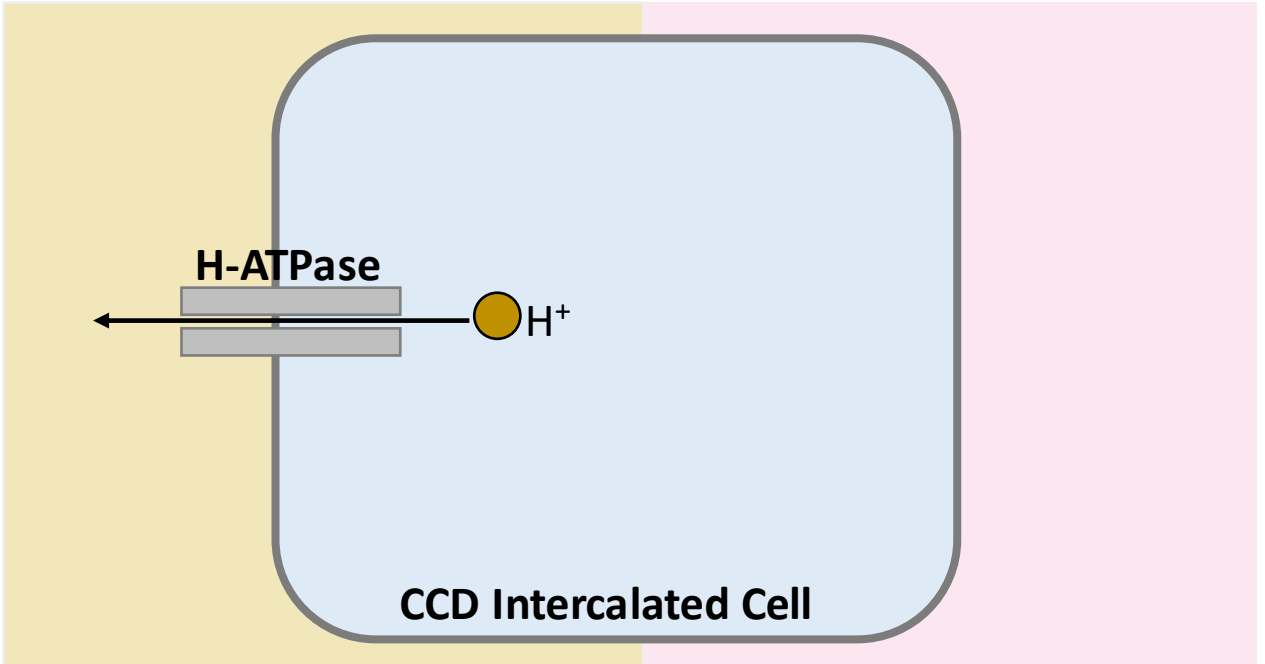
- Cells of the CD:
  - Principal cells
  - Intercalated cells
    - A
    - B

CCD Normal Physiology



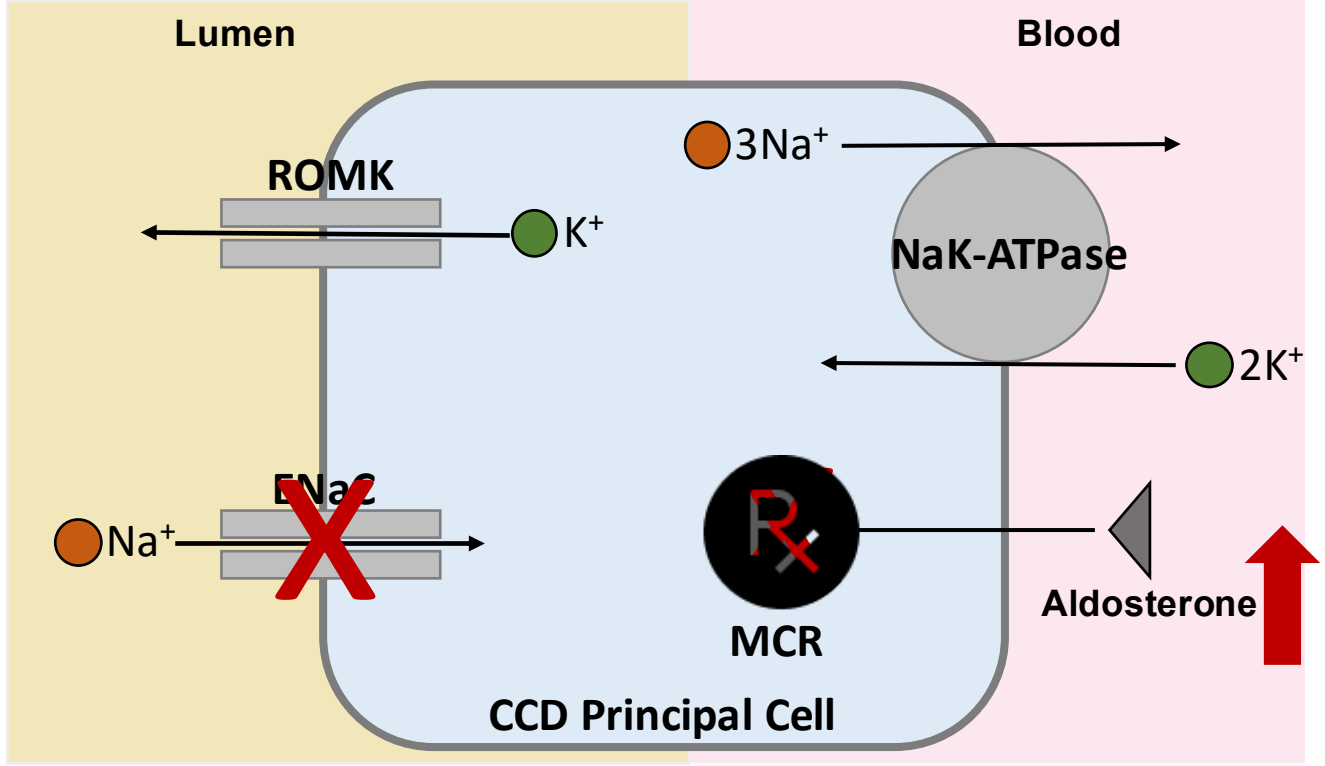


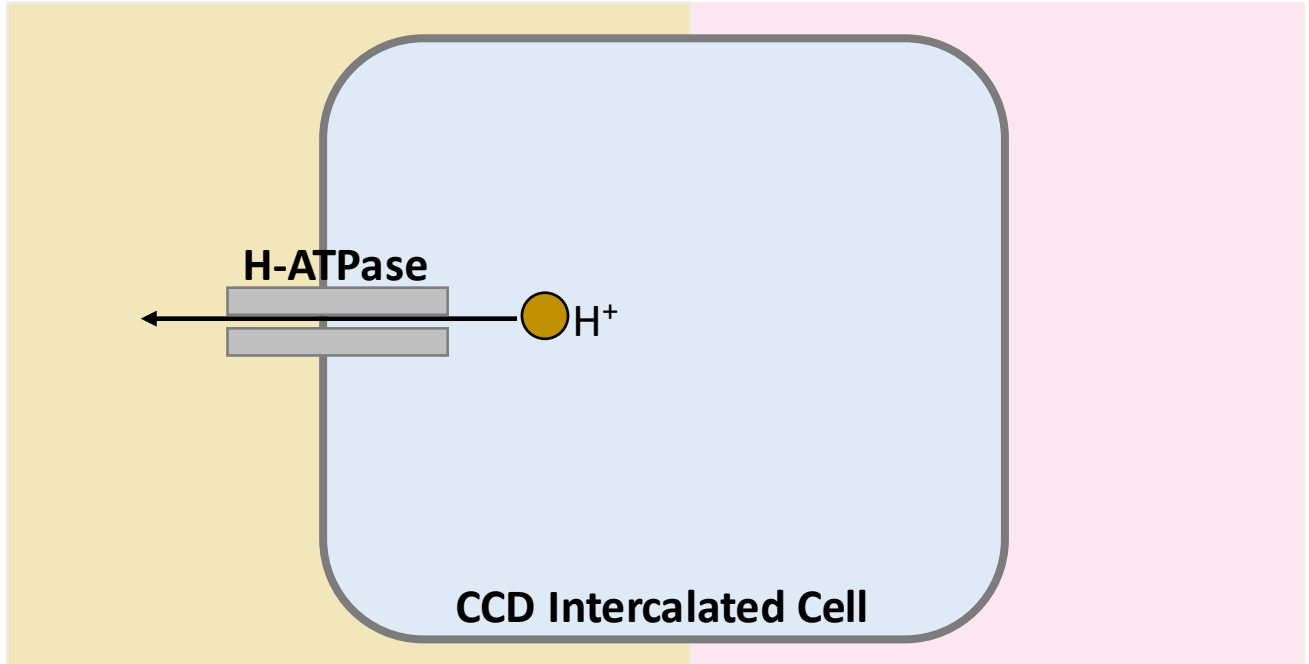
RAAS
Potassium



PHA Type 1 Pathophysiology

- Hyponatremia
- Hyperkalemia
- Acidosis
- Hyperaldosteronism





Thank you

Questions?

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