1878

Western

UNIVERSITY · CANADA

Tutorial 15
Sections 009/010

TA: Greydon Gilmore
Physiology 2130
Jan 28th, 2020

Western

Your TA reminding you…

- **3rd Peerwise assignment** (1.5%)
  - Post 2 MC questions: due Feb 12th @ midnight
  - Answer 5 MC questions: due Feb 14th @ midnight
- **3rd Quiz** (1%)
  - Opens: Feb 24th @ 4pm
  - Closes: Feb 25th @ 4pm
- **3rd Midterm** (15%)
  - When: Feb 28th @ 6pm-7pm

Today

- Group work activity
- Feedback survery
- Learning Catalytics Question
- Renal Physiology

Review from last week

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Calculate Sandra's GFR

$[Sodium]_{plasma}$ = 8 mg/L $[Potassium]_{plasma}$ = 2 mg/L $[Creatinine]_{plasma}$ = 2 mg/L $[Glucose]_{plasma}$ = 15 mg/L $[Magnesium]_{plasma}$ = 20 mg/L	$[Sodium]_{urine}$ = 10 mg/L $[Potassium]_{urine}$ = 12 mg/L $[Creatinine]_{urine}$ = 120 mg/L $[Glucose]_{urine}$ = 0 mg/L $[Magnesium]_{urine}$ = 15 mg/L
Urine volume = 2.5 L/day	

GFR *=* $[creatinine]_{urine}$ ** total urine volume/*$[creatinine]_{plasma}$

GFR *= (120 mg/L * 2.5 L/day)/ 2 mg/L = 150 L/day*

What is the filtered load of sodium

$[Sodium]_{plasma}$ = 8 mg/L $[Potassium]_{plasma}$ = 2 mg/L $[Creatinine]_{plasma}$ = 2 mg/L $[Glucose]_{plasma}$ = 15 mg/L $[Magnesium]_{plasma}$ = 20 mg/L	$[Sodium]_{urine}$ = 10 mg/L $[Potassium]_{urine}$ = 12 mg/L $[Creatinine]_{urine}$ = 120 mg/L $[Glucose]_{urine}$ = 0 mg/L $[Magnesium]_{urine}$ = 15 mg/L
Urine volume = 2.5 L/day	

filtered load of sodium *=* $[Sodium]_{plasma}$ ** GFR*

filtered load of sodium *= 8 mg/L * 150 L/day = 2250 mg/day*

What is the filtered load of glucose

$[\text{Sodium}]_{plasma}$ = 8 mg/L $[\text{Potassium}]_{plasma}$ = 2 mg/L $[\text{Creatinine}]_{plasma}$ = 2 mg/L $[\text{Glucose}]_{plasma}$ = 15 mg/L $[\text{Magnesium}]_{plasma}$ = 20 mg/L	$[\text{Sodium}]_{urine}$ = 10 mg/L $[\text{Potassium}]_{urine}$ = 12 mg/L $[\text{Creatinine}]_{urine}$ = 120 mg/L $[\text{Glucose}]_{urine}$ = 0 mg/L $[\text{Magnesium}]_{urine}$ = 15 mg/L
Urine volume = 2.5 L/day	

filtered load of glucose *=* $[\text{Glucose}]_{plasma}$ ** GFR*
filtered load of glucose *= 15 mg/L * 150 L/day = 2250 mg/day*

What is the filtered load of magnesium

$[Sodium]_{plasma}$ = 8 mg/L $[Potassium]_{plasma}$ = 2 mg/L $[Creatinine]_{plasma}$ = 2 mg/L $[Glucose]_{plasma}$ = 15 mg/L $[Magnesium]_{plasma}$ = 20 mg/L	$[Sodium]_{urine}$ = 10 mg/L $[Potassium]_{urine}$ = 12 mg/L $[Creatinine]_{urine}$ = 120 mg/L $[Glucose]_{urine}$ = 0 mg/L $[Magnesium]_{urine}$ = 15 mg/L
Urine volume = 2.5 L/day	

filtered load of magnesium *= $[Magnesium]_{plasma}$ * GFR*
filtered load of magnesium *= 20 mg/L * 150 L/day = 3000 mg/day*

What is the renal handling for potassium

$[Sodium]_{plasma}$ = 8 mg/L $[Potassium]_{plasma}$ = 2 mg/L $[Creatinine]_{plasma}$ = 2 mg/L $[Glucose]_{plasma}$ = 15 mg/L $[Magnesium]_{plasma}$ = 20 mg/L	$[Sodium]_{urine}$ = 10 mg/L $[Potassium]_{urine}$ = 12 mg/L $[Creatinine]_{urine}$ = 120 mg/L $[Glucose]_{urine}$ = 0 mg/L $[Magnesium]_{urine}$ = 15 mg/L
Urine volume = 2.5 L/day	

1. **First calculate the filtered load of potassium:**

   filtered load of potassium *=* $[Potassium]_{plasma}$ ** GFR*

   filtered load of potassium *= 2 mg/L * 150 L/day = 300 mg/day*

2. **How much potassium is excreted per day?**

   Rate of potassium excretion *=* $[Potassium]_{urine}$ ** total urine volume*

   Rate of potassium excretion *= 12 mg/L * 2.5 L/day = 30 mg/day*

3. **Determine % reabsorption (to determine renal handling)**

   % reabsorbed *= (K^+ filtered load – K^+ excretion rate)/ K^+ filtered load *100*

   % reabsorbed *= (300 mg/day – 30 mg/day)/300 mg/day *100 = 90% reabsorbed*

Calculate the net filtration pressure if the forces are determined as the following

P_{GC} = 60 mmHg
P_{BC} = 35 mmHg
π_{GC} = 25 mmHg
π_{BC} = 5 mmHg

NFP *=* $(P_{GC} + \Pi_{BC}) - (P_{BC} + \Pi_{GC})$

NFP *= (60 mmHg + 5 mmHg) – (35 mmHg + 25 mmHg)*

NFP *= 5 mmHg*

1. **Is this person filtering a normal volume, less or more volume of fluid per day?**

   Since it is less than normal, this person would filter less fluid per day than a healthy individual.

Group Work

Build A Concept Map

As a group, place all of the following words in a concept map to help summarize renal physiology. All words in this list must be connected to at least one other word. Add connecting words as necessary (ie. increases, decreases, if, when, detects, released, etc.) and additional renal terminology to your map as you wish. You can also add images to your map.

- ADH
- Afferent arteriole
- Aldosterone
- Angiotensin II
- Ascending limb
- Baroreceptor
- Collecting duct
- Creatinine
- Glomerulus
- Proximal tubule
- Descending limb
- Distal convoluted tubule

- Efferent arteriole
- GFR
- High urine volume
- Impermeable to water
- Juxtaglomerular cells
- Low urine volume
- Macula densa
- Osmoreceptor
- Reasborbs ions
- Renin
- Sodium
- Water

Feedback Survey

https://uwo.eu.qualtrics.com/jfe/form/SV_4MCJLtiTiXtBUvr

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Learning Catalytic Question

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Transport Mechanisms

Chapter 8: Dr. Woods

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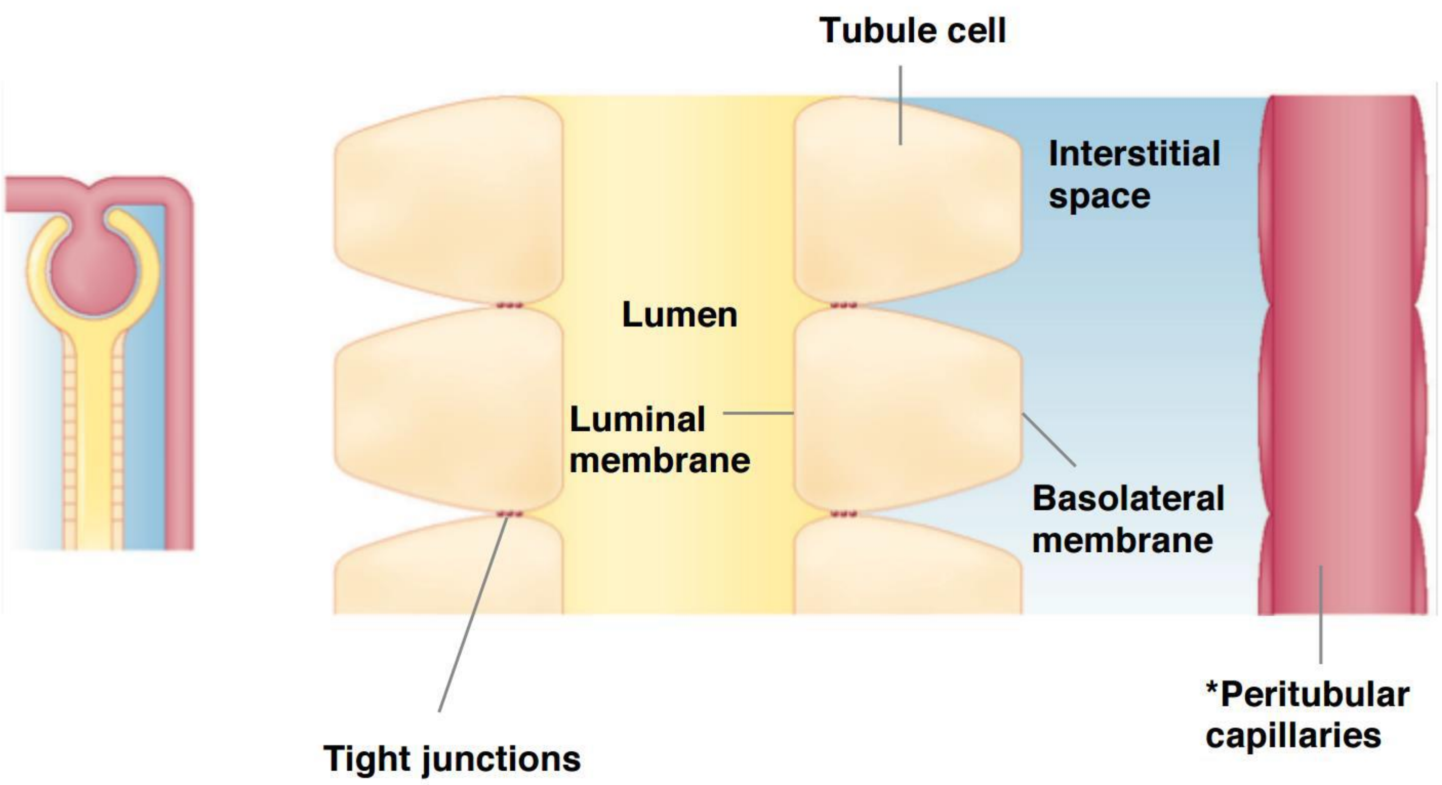
Cells of the Tubule



Cells of the Tubule

Reabsorption

Transcellular:

- Two-step process
- Moves through luminal, then basolateral membrane

Paracellular:

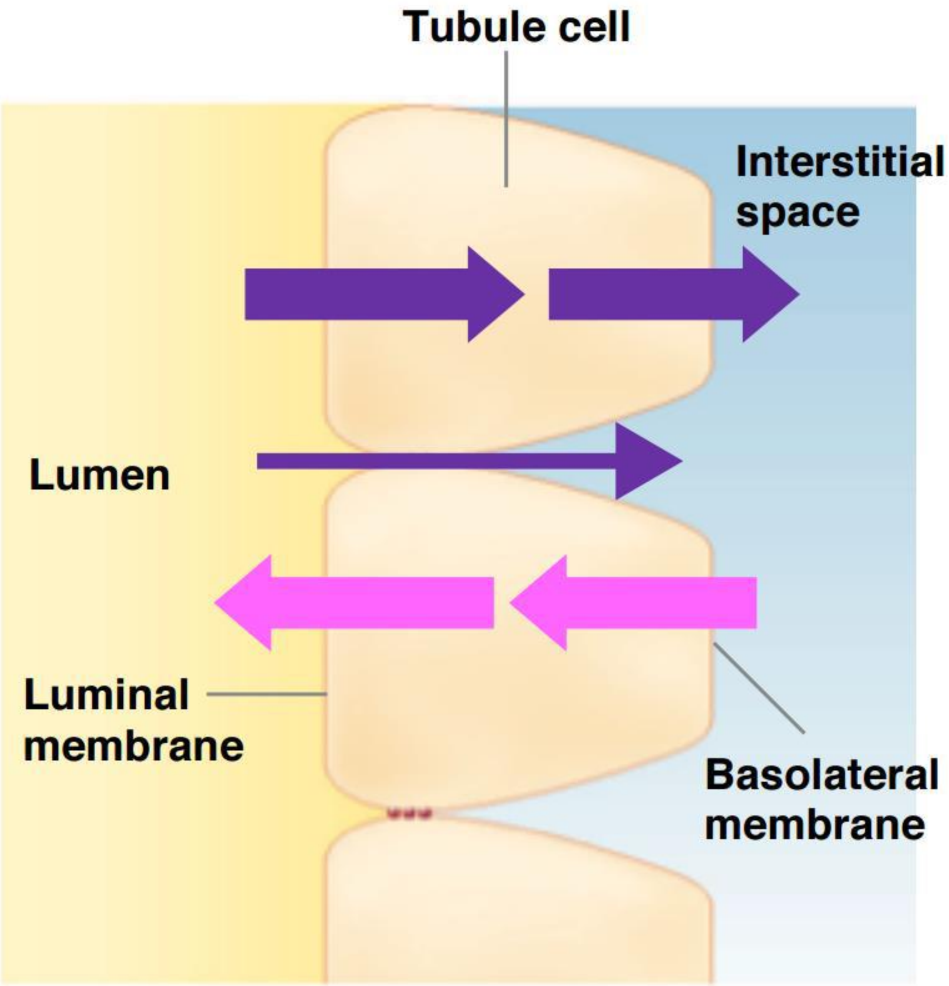
- One-step process
- In between tubule cells

Secretion

Always Transcellular:

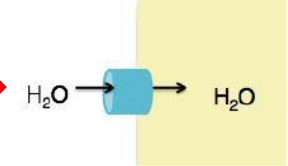
- Moves through basolateral, then luminal membrane

No Paracellular

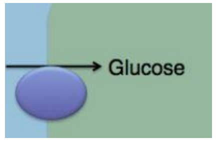


Review of Transport Mechanisms

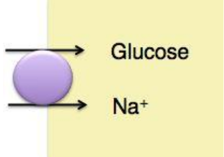
- Channels: Passive diffusion through a protein pore in membrane (ex: aquaporin)



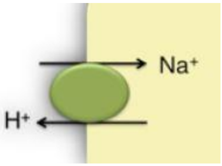
- Transporters: Carries molecule across membrane
  - Uniporters: Move a single molecule across membrane (ex: glucose uniporter)



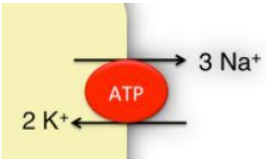
  - Symporters: Moves two molecules in the same direction across membrane. At least one molecule must move down its concentration gradient (ex: Na+/glucose symporter)



  - Antiporters: Moves two molecules in opposite directions across membrane. At least one molecule must move down its concentration gradient (ex: Na^+/H^+ antiporter)

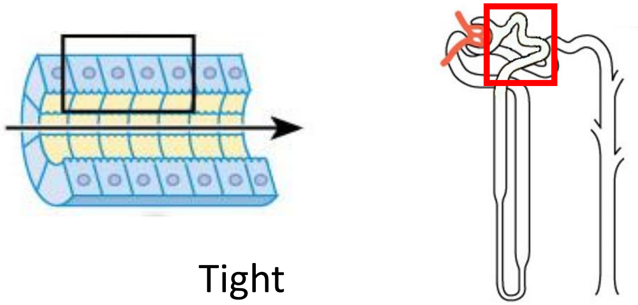


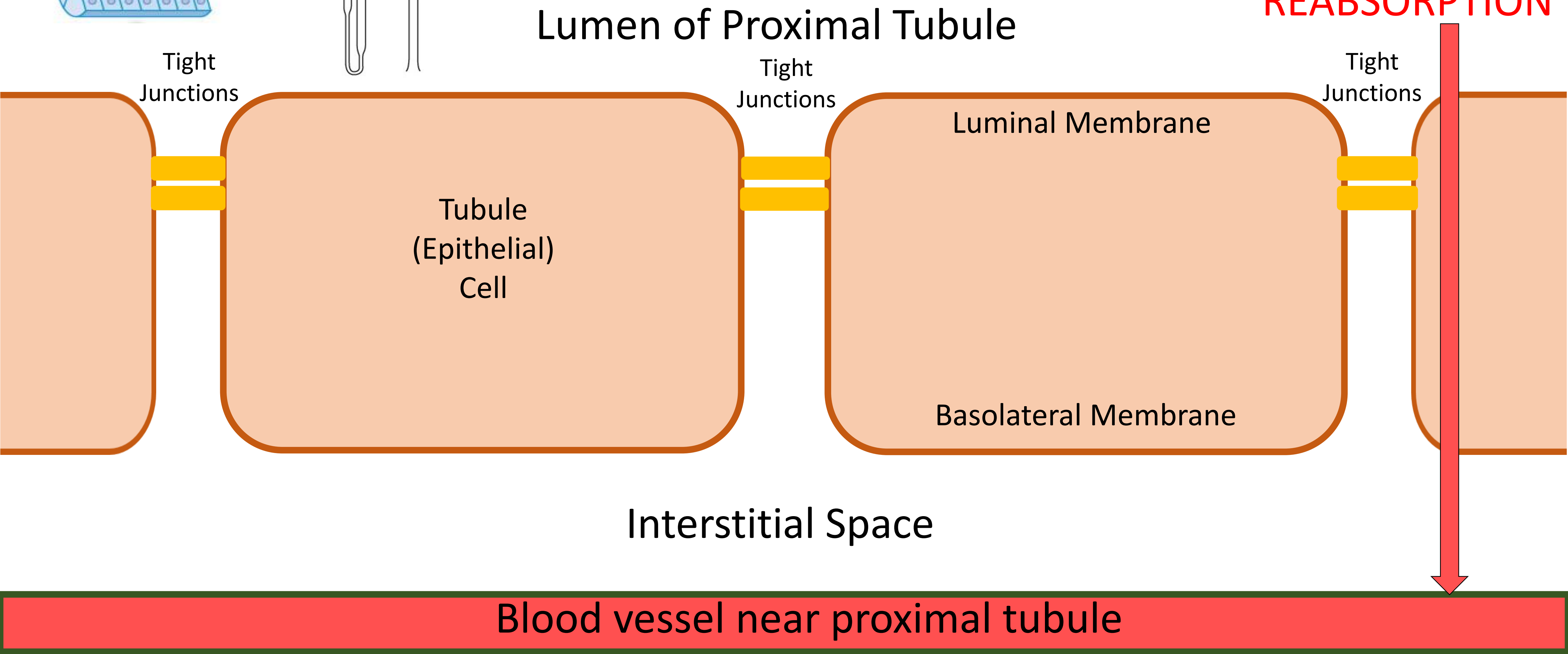
- Primary Active Transporters: Require ATP to move molecules against their concentration gradients (ex: Na^+/K^+ ATPase)



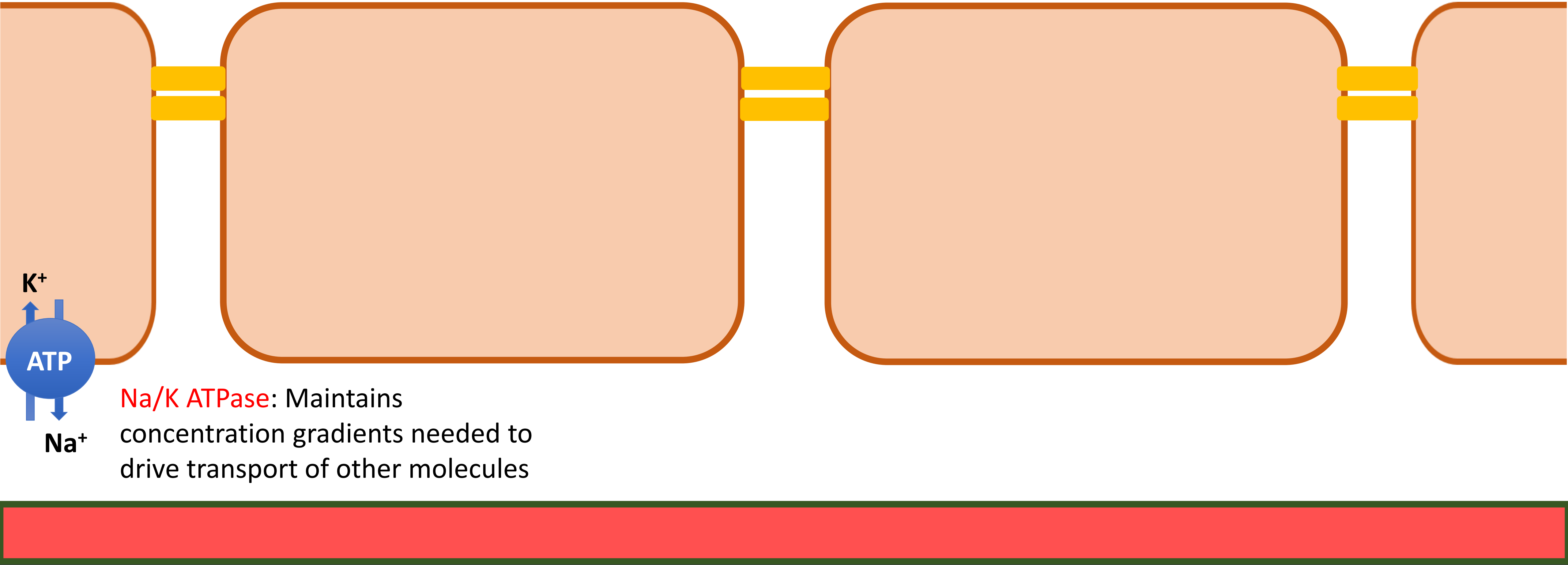
Proximal Tubule

Overall Goal: REABSORPTION





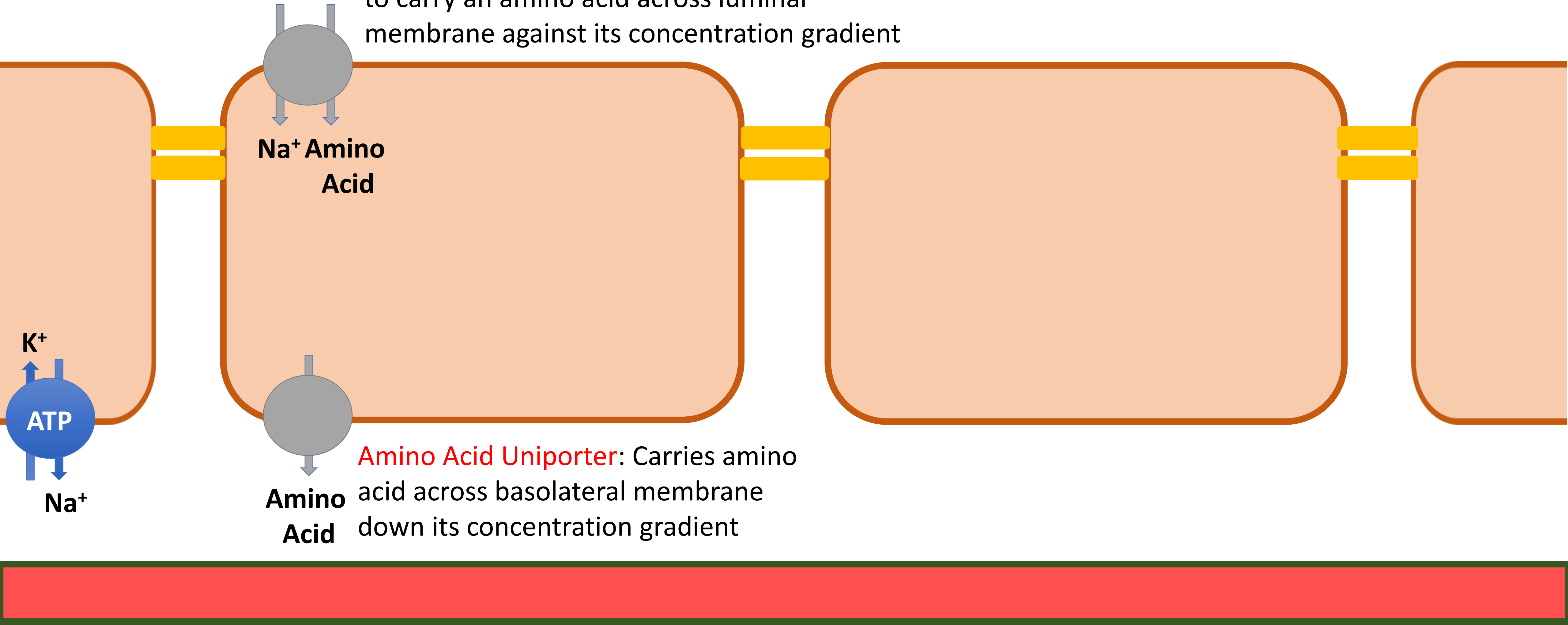
Sodium Potassium Pump



Na/K ATPase: Maintains concentration gradients needed to drive transport of other molecules

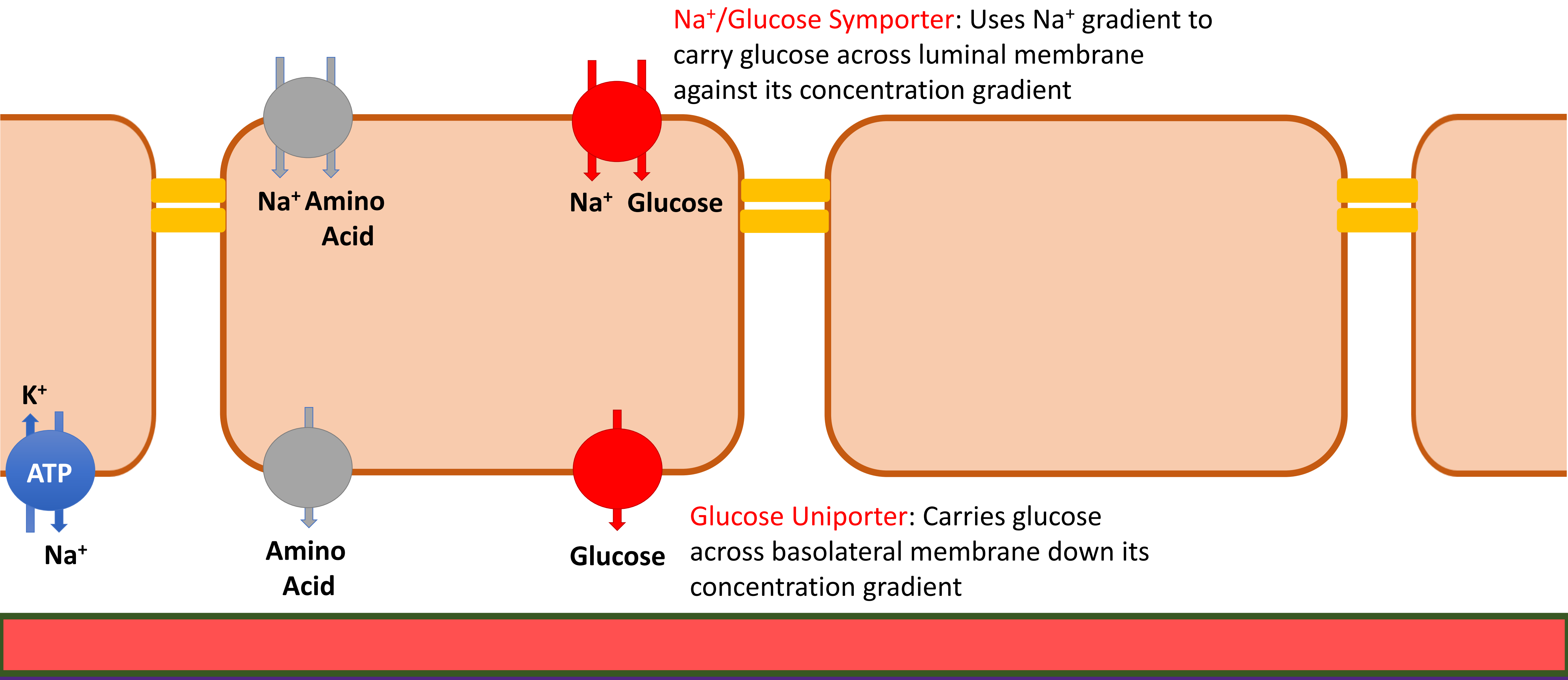
Reabsorbing Amino Acids

Na+/Amino Acid Symporter: Uses Na^+ gradient to carry an amino acid across luminal membrane against its concentration gradient

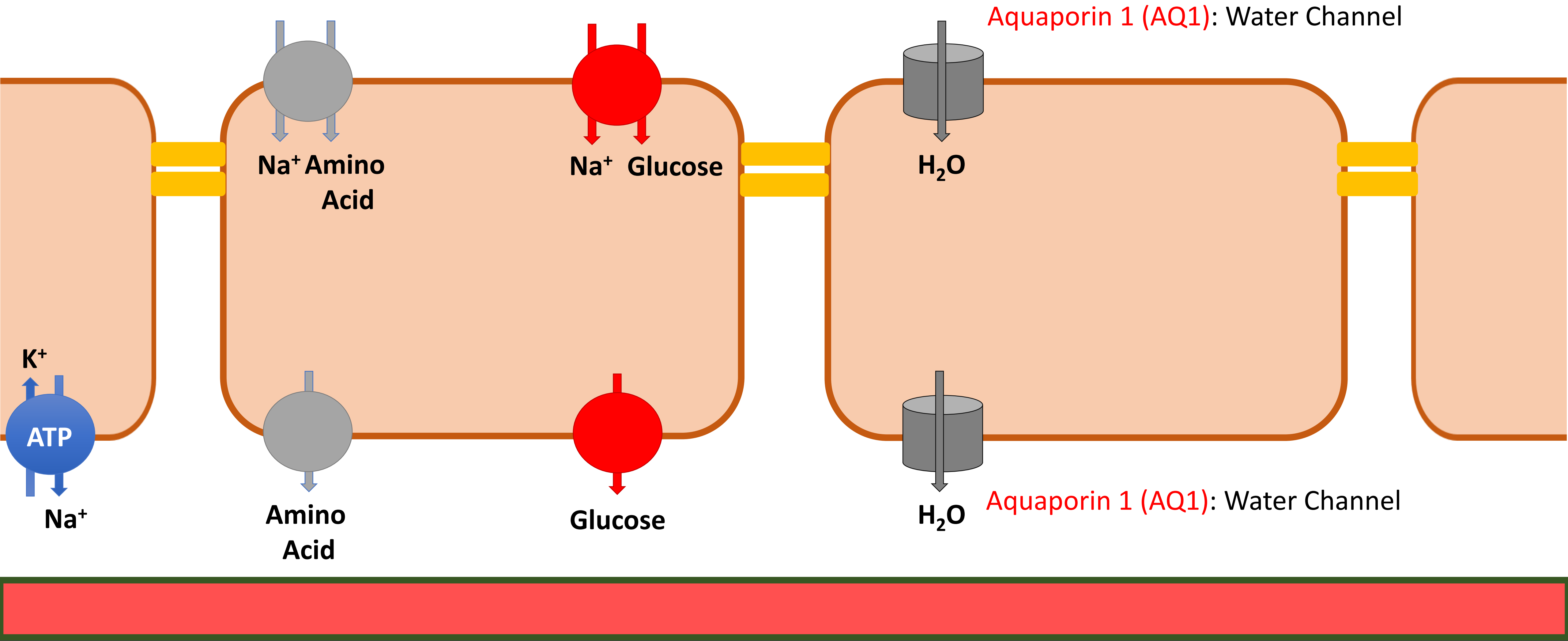


Amino Acid Uniporter: Carries amino acid across basolateral membrane down its concentration gradient

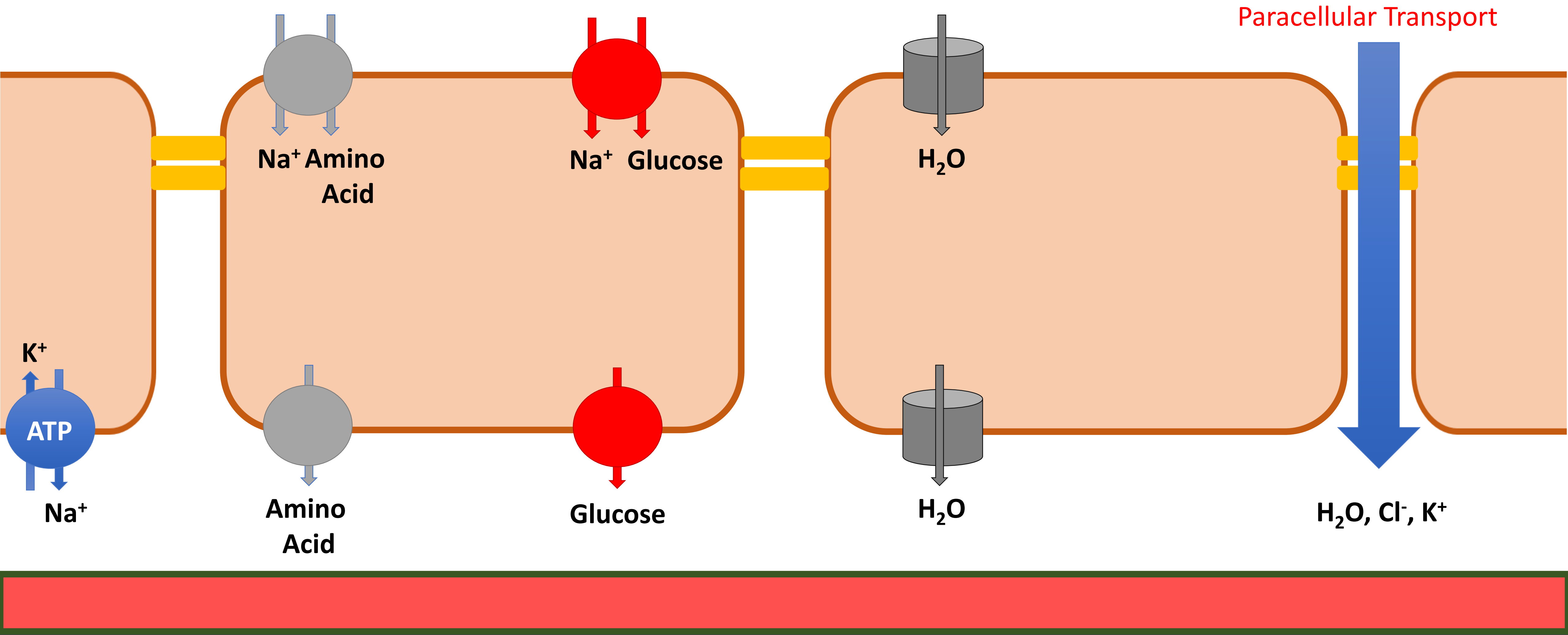
Reabsorbing Glucose (100%)



Reabsorbing Water



Reabsorbing Ions and More Water



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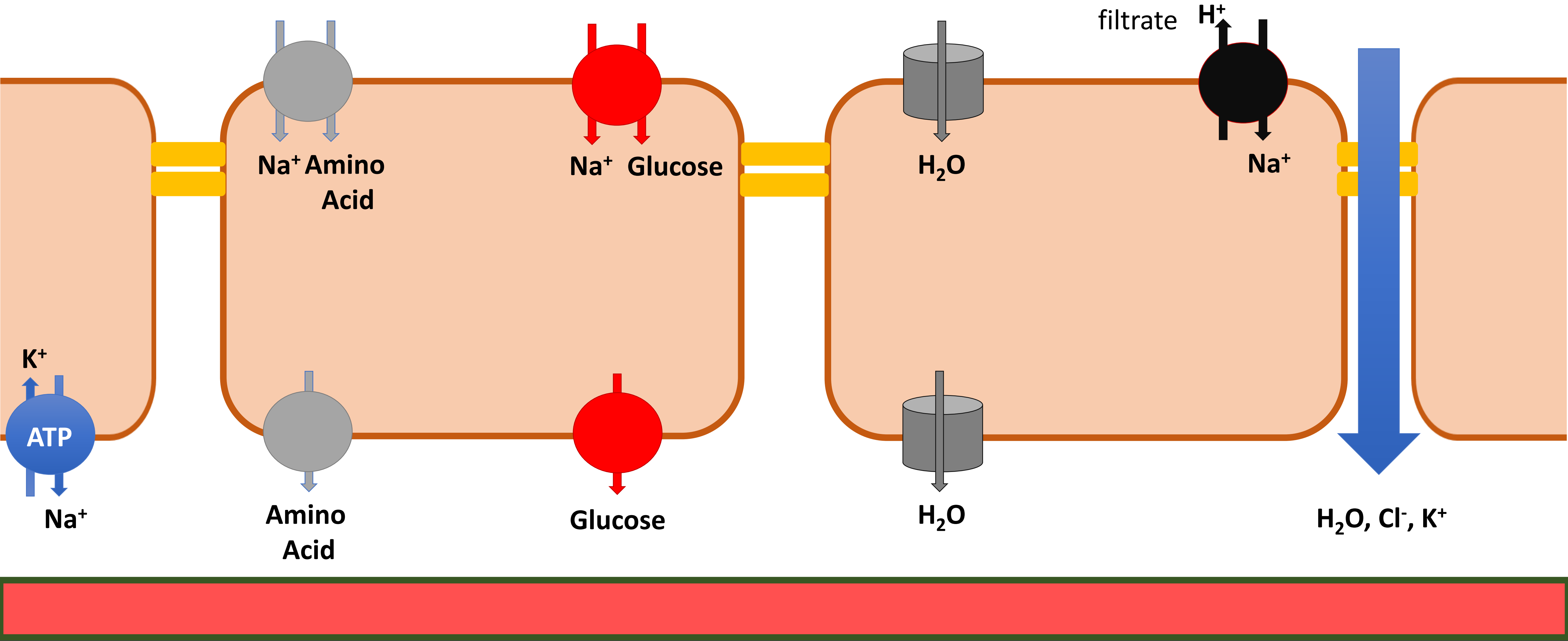
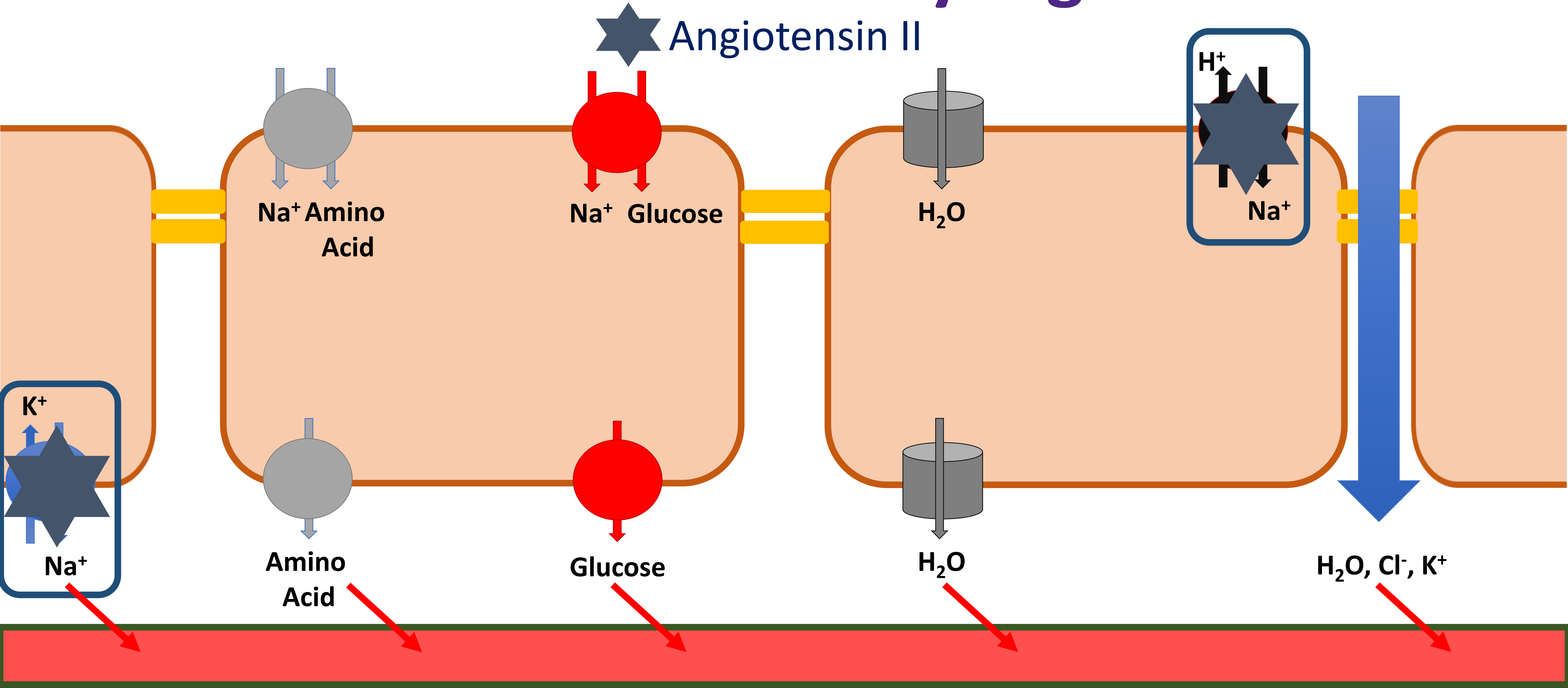
Regulating pH of filtrate/urine

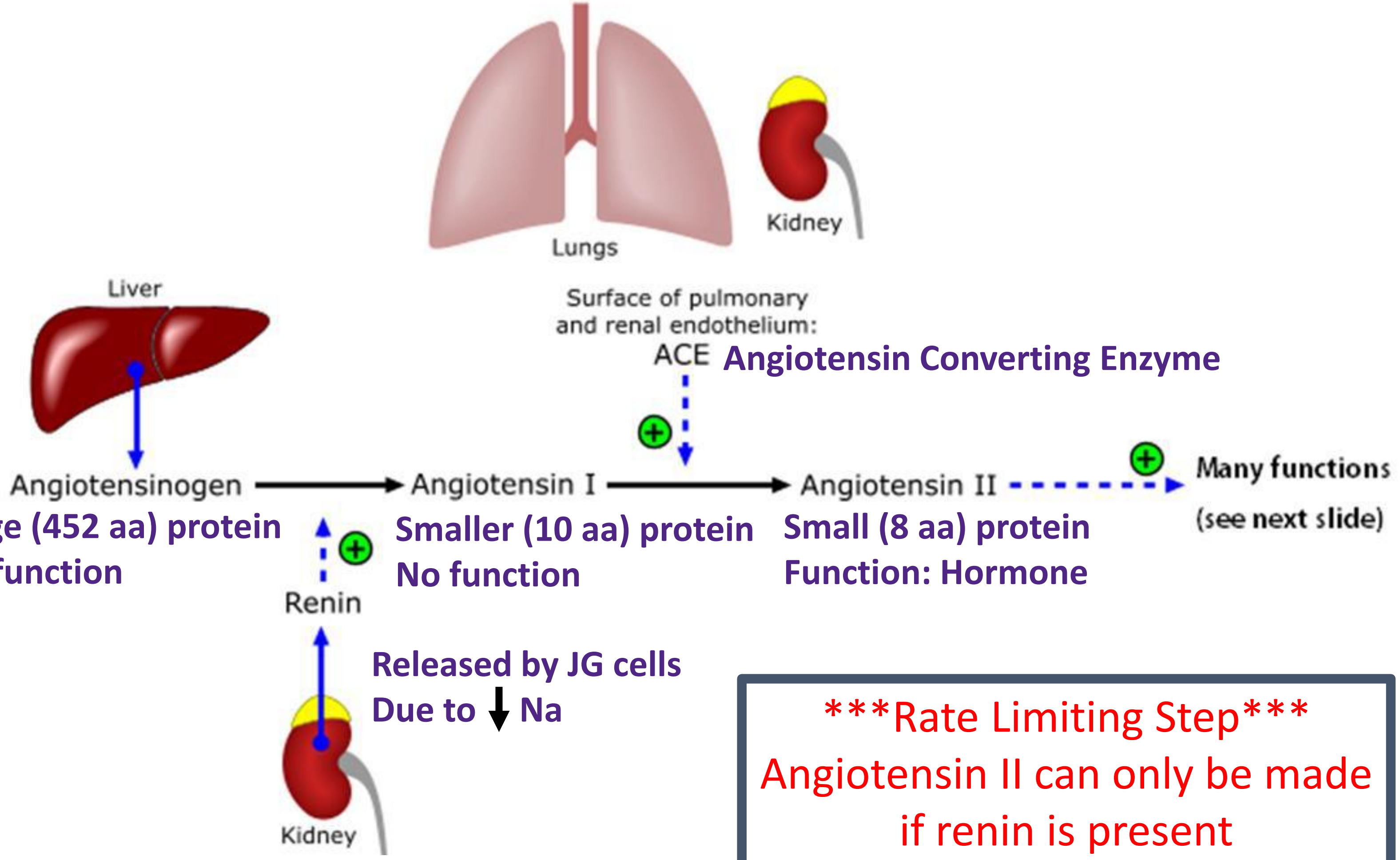
Na/H+Antiporter/Exchanger: Uses Na gradient to carry H+ across luminal membrane into filtrate



Which are hormonally regulated?



RAAS



Angiotensin Converting Enzyme

Large (452 aa) protein
No function

Smaller (10 aa) protein
No function

Small (8 aa) protein
Function: Hormone

Released by JG cells
Due to ↓ Na

Rate Limiting Step
Angiotensin II can only be made if renin is present

Angiotensin II

- Made by cleavage of:

  angiotensinogen ➡ angiotensin I ➡ angiotensin II

- Peptide hormone (= requires cell-surface receptor on luminal membrane)

Stimulus

- Release of renin by JG cells due to ↓ Na^+

Goal

- Increase Na^+ reabsorption in proximal tubule

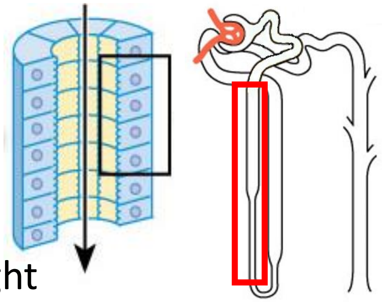
How

1. Increase activity of Na^+ /H^+ exchanger and Na^+ /K^+ ATPase in proximal tubule
2. Decrease GFR by constricting afferent arteriole

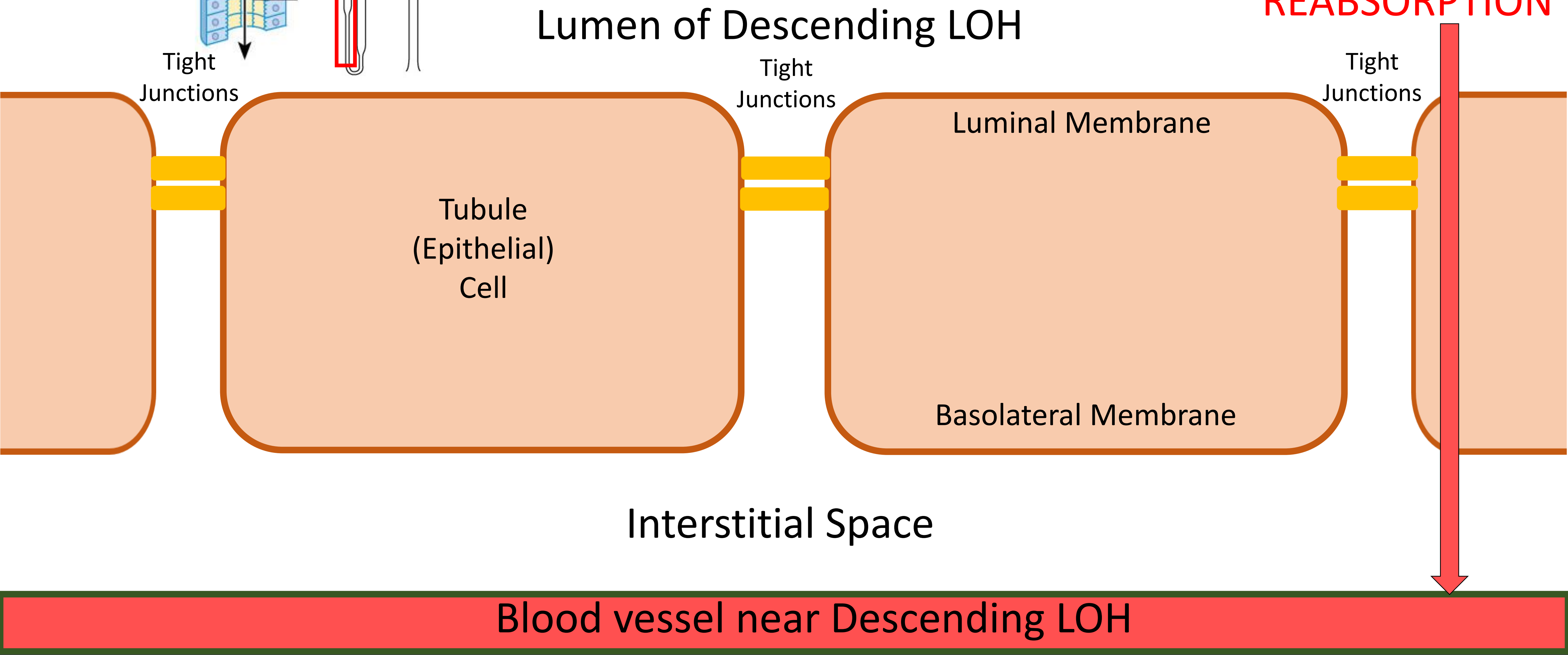
Renin

- Renin released due to low sodium levels

Descending LOH



Overall Goal: REABSORPTION



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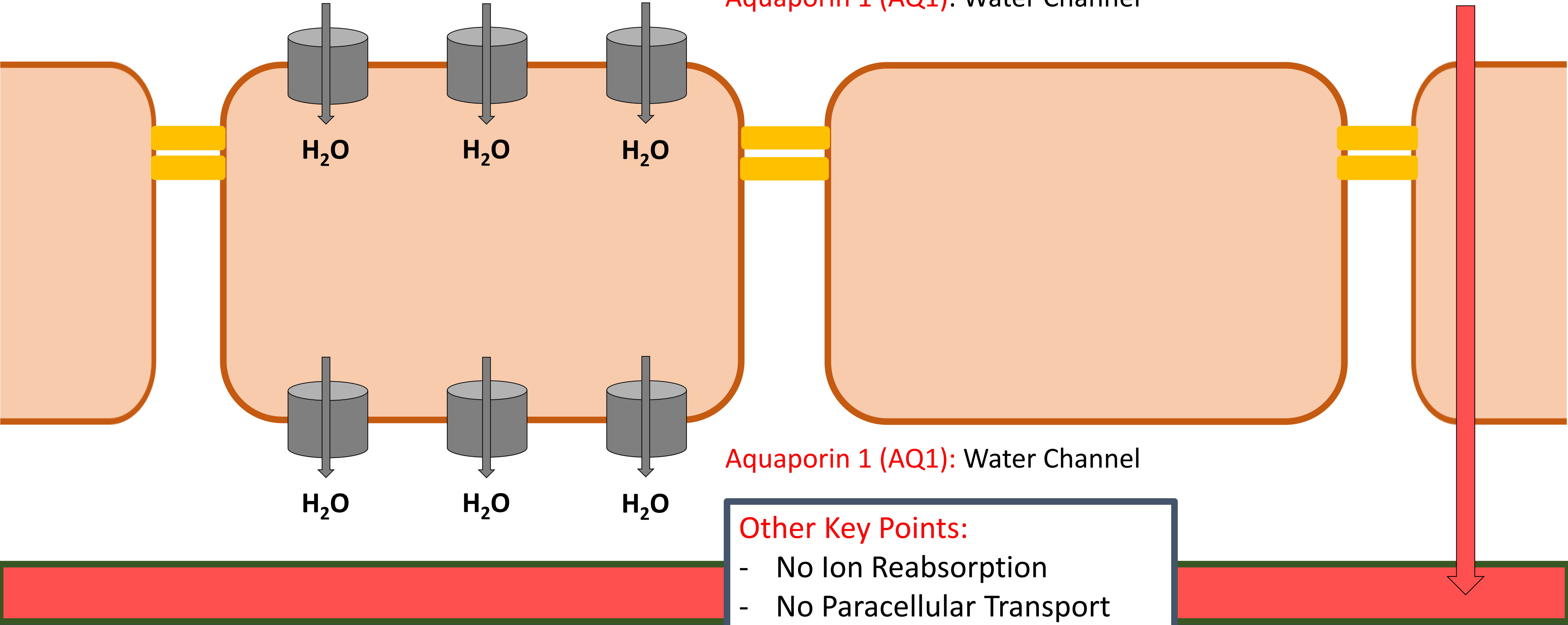
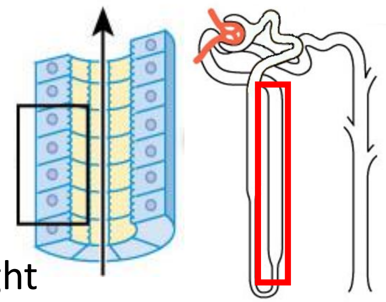
Descending LOH

Overall Goal: REABSORPTION



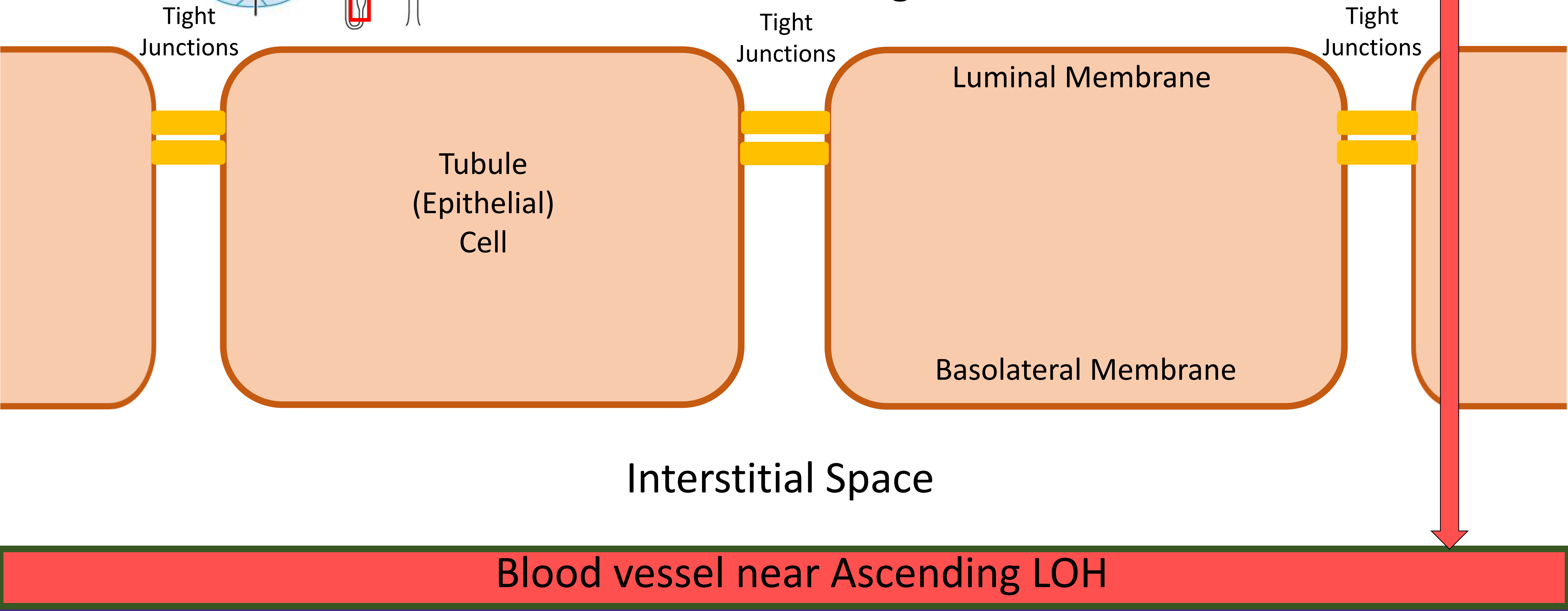
Other Key Points:
- No Ion Reabsorption
- No Paracellular Transport
- No Hormonal Regulation

Ascending LOH



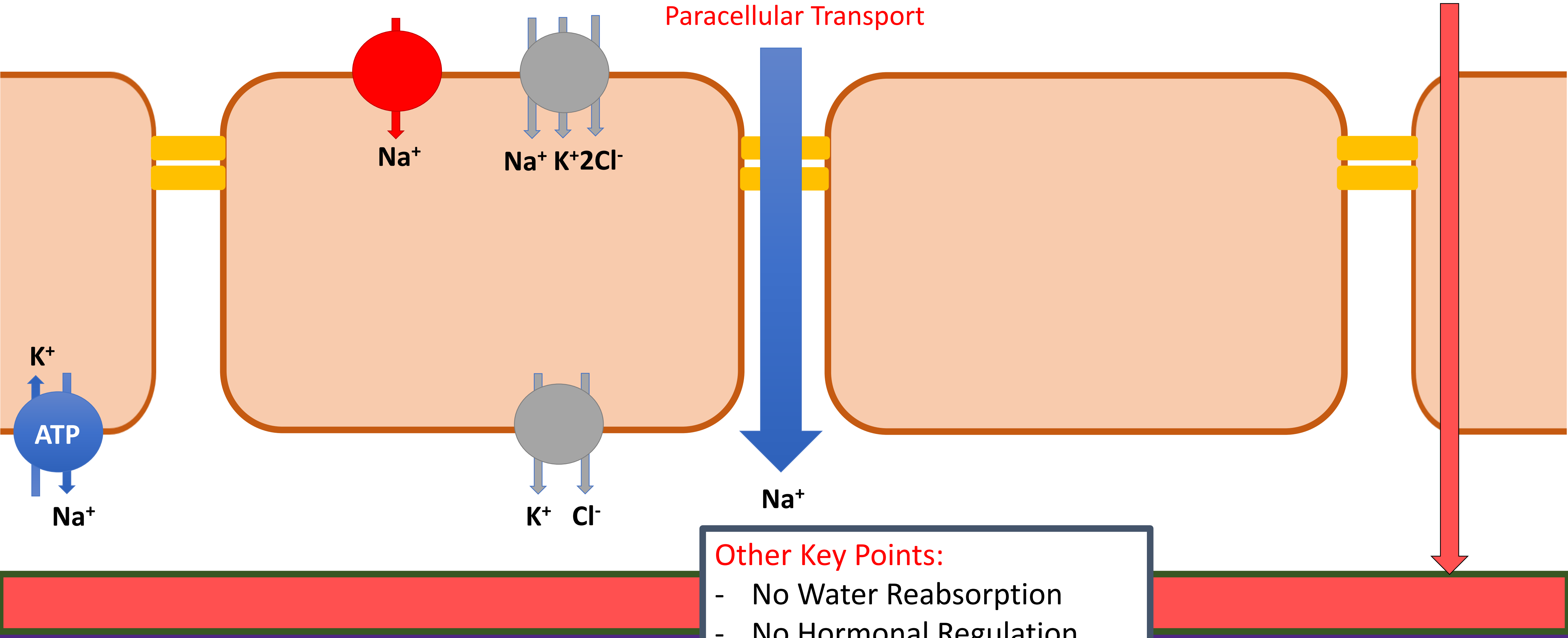
Lumen of Ascending LOH

Overall Goal:
REABSORPTION



Ascending LOH

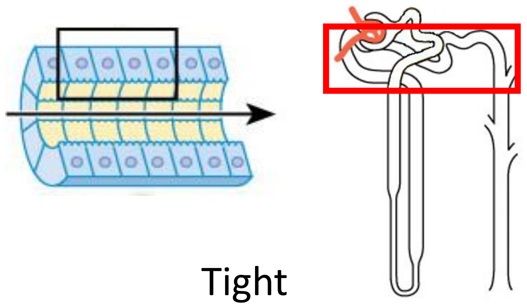
Overall Goal:
REABSORPTION



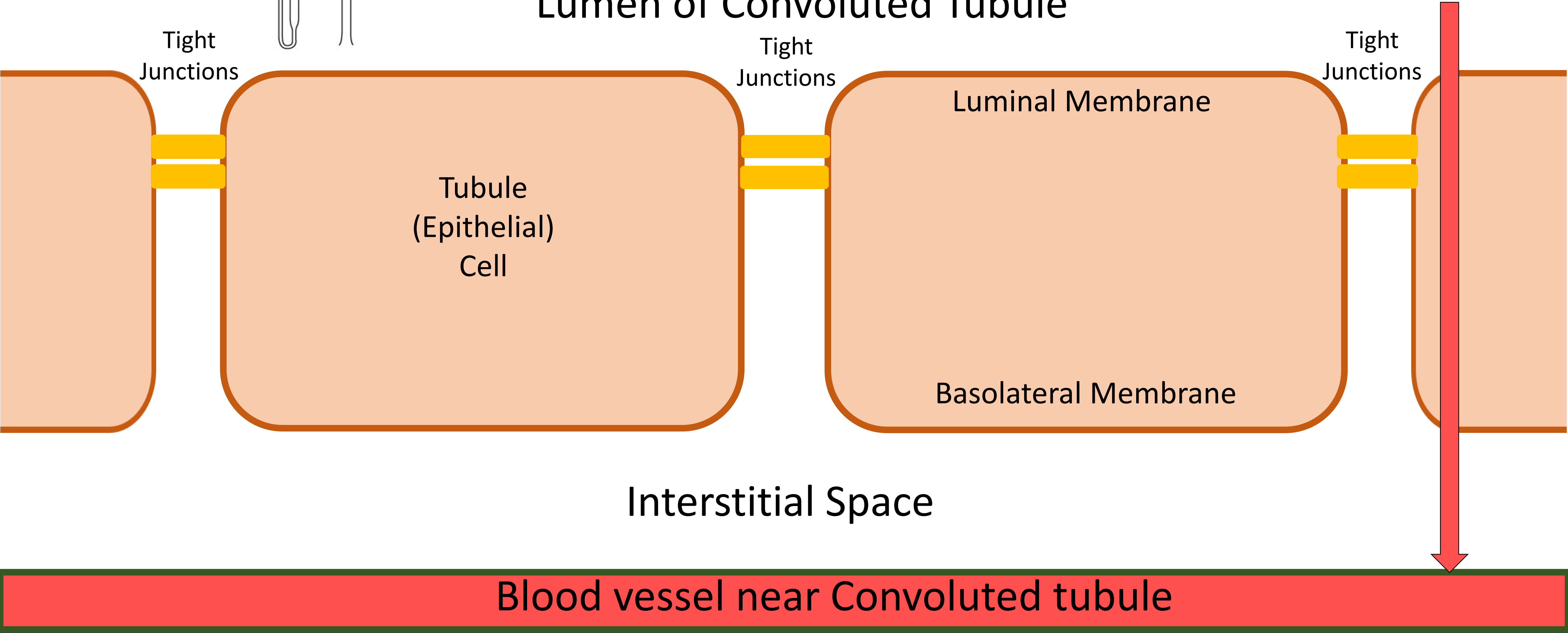
Other Key Points:

- No Water Reabsorption
- No Hormonal Regulation

Distal Convoluted Tubule

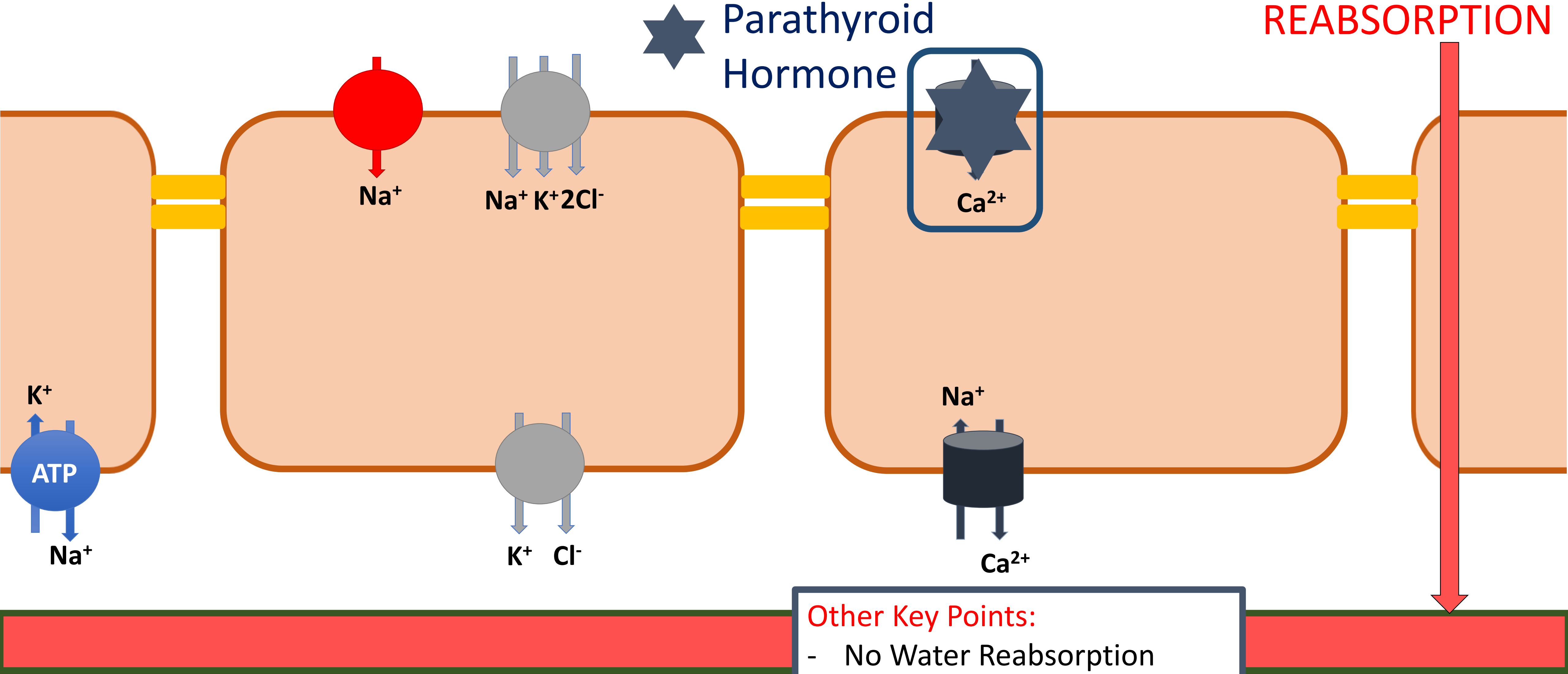


Overall Goal:
REABSORPTION



Distal Convoluted Tubule

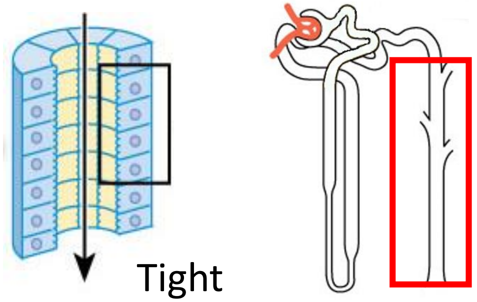
Overall Goal:
REABSORPTION

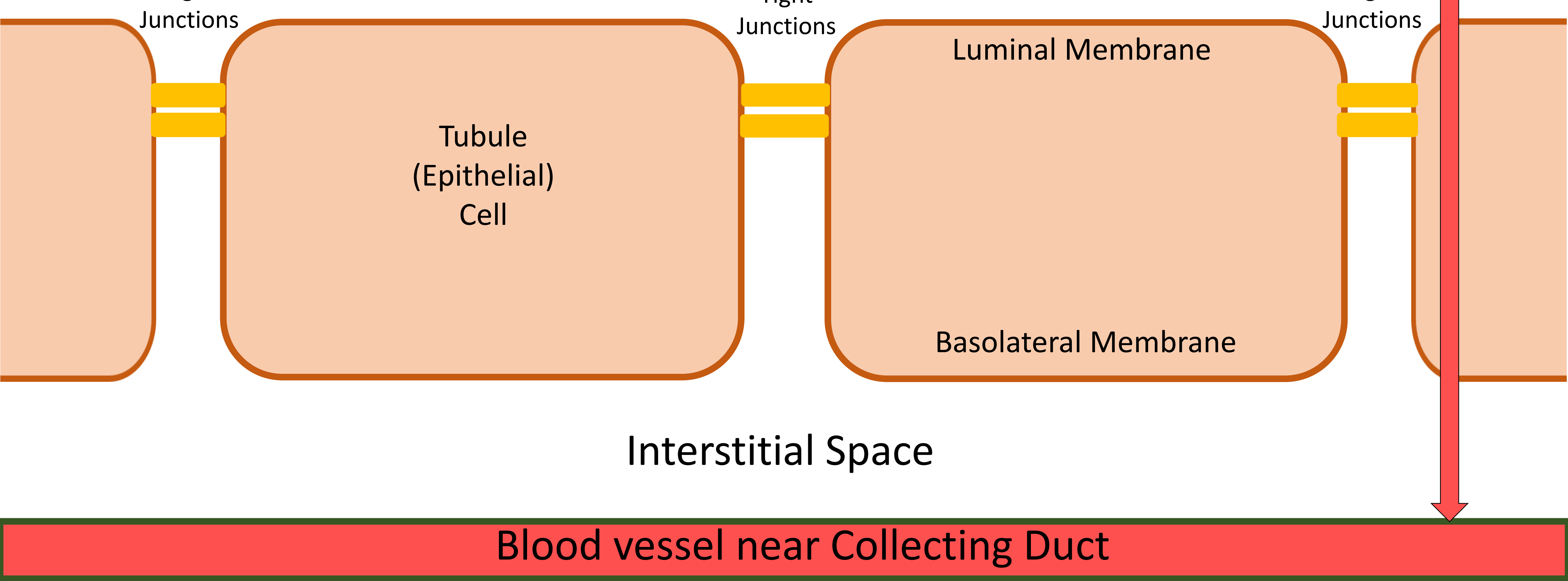


Other Key Points:

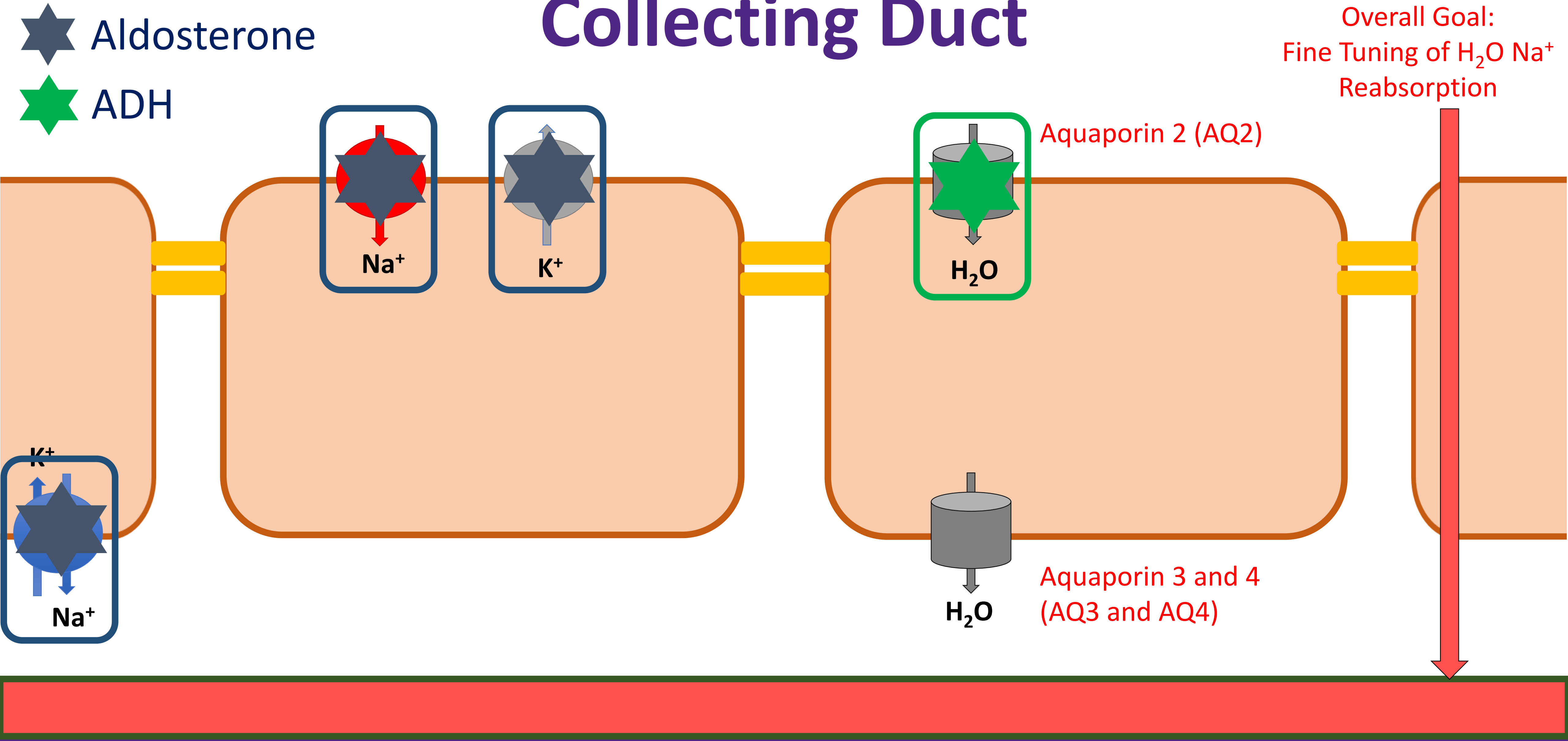
- No Water Reabsorption
- No Paracellular Transport

Collecting Duct





Collecting Duct



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Aldosterone

- Made by adrenal gland
- Steroid hormone (= intracellular receptor)

Stimulus

- Angiotensin II, High K^+, ACTH

Goal

- Increase Na^+ reabsorption in collecting duct

How

1. ↑ Na^+ and K^+ channels in luminal membrane: by translocation and protein expression
2. ↑ Na^+ /K^+ ATPase activity and protein expression

Anti-Diuretic Hormone (aka Vasopressin)

- Made by hypothalamus (by neuroendocrine cells)
  - stored/released by posterior pituitary
- Peptide hormone (= requires cell-surface receptor on basolateral membrane)

Stimulus

High plasma osmolarity = Low ECF volume = Low BP

Goal

↑ water reabsorption = ↑ ECF volume = ↑ BP

Anti-Diuretic Hormone (aka Vasopressin)

↑ plasma osmolarity (fluid is hyperosmotic)

↓

Osmoreceptors (in hypothalamus) shrink

↓

ADH is released from posterior pituitary

↓

Travels in blood to collecting duct

↓

Binds to receptors on basolateral membrane

↓

Increases # of AQ2 channels on luminal membrane

↓

↑ water reabsorption

Anti-Diuretic Hormone (aka Vasopressin)

↓ BV = ↓BP

⬇

Baroreceptors (in aortic arch and carotid sinus) fire less AP to hypothalamus

⬇

ADH is released from posterior pituitary

⬇

Travels in blood to collecting duct

⬇

Binds to receptors on basolateral membrane

⬇

Increases # of AQ2 channels on luminal membrane

⬇

↑ water reabsorption = ↑BV = ↑BP

Atrial Natriuretic Peptide (ANP)

- Made by cardiac atrial cells
- Peptide hormone

Stimulus

- High blood pressure

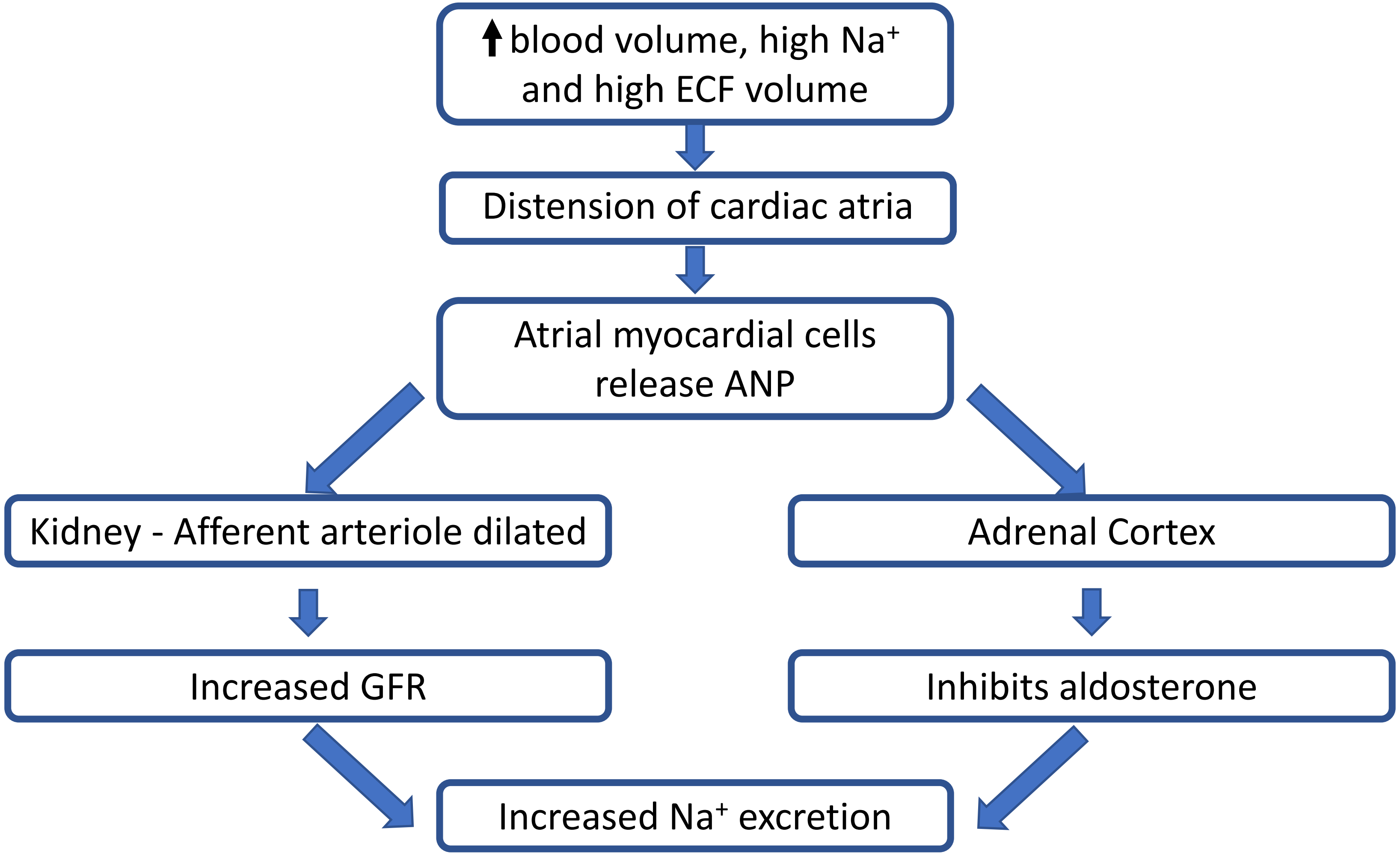
Goal

- Decrease Na^+ reabsorption

How

- Inhibits aldosterone secretion by adrenal glands
- Dilates afferent arterioles → increasing GFR
  - This increases flow of filtrate through tubule, leads to increase in Na^+ excretion

Atrial Natriuretic Peptide (ANP)



Summary of Transport

	Proximal Tubule	Descending Limb	Ascending Limb	Distal Tubule	Collecting Duct
Goal	Reabsorption of everything	Water reabsorption	Ion reabsorption	Ion reabsorption	Fine tuning (water and Na)
Water	Yes	Yes	No	No	Yes
Ions	Yes (Na^+, Cl^-, K^+)	Minimal (Na^+)	Yes (Na^+, Cl^-, K^+)	Yes (Na^+, Cl^-, K^+, Ca^{2+})	Yes (Na^+)
Paracellular Transport	Yes	No	Yes	No	No
Hormone Regulation	Angiotensin II	-	-	PTH	Aldosterone ADH

Summary of Hormonal Regulation

Hormone	Made By	Hormone Type	Stimulus	Response
Renin	Kidneys	N/A	Increased sodium	N/A
Angiotensin II	Angiotensin Converting Enzyme	Peptide	Renin – released due to low sodium	Increase sodium reabsorption in proximal tubule: 1. Increase activity of Na^+/H^+ exchanger and Na^+/K^+ ATPase 2. Constrict afferent arteriole (decreasing GFR)
Aldosterone	Adrenal Gland	Steroid	Angiotensin II and high K^+	Increase sodium reabsorption in collecting duct: 1. Increase Na^+ and K^+ channels in luminal membrane 2. Increase activity of Na^+/K^+ ATPase
Atrial Natriuretic Peptide	Cardiac atrial cells	Peptide	High blood pressure	Decrease sodium reabsorption: 1. Inhibit aldosterone secretion from adrenal glands 2. Dilates afferent arteriole (increasing GFR)

Next Tutorial (Feb 4th)

- Respiratory physiology!

What Questions Do You Have?

You can ask in the **Owl forums** as well!

Also anonymously ask questions in the **online dropbox**!!

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