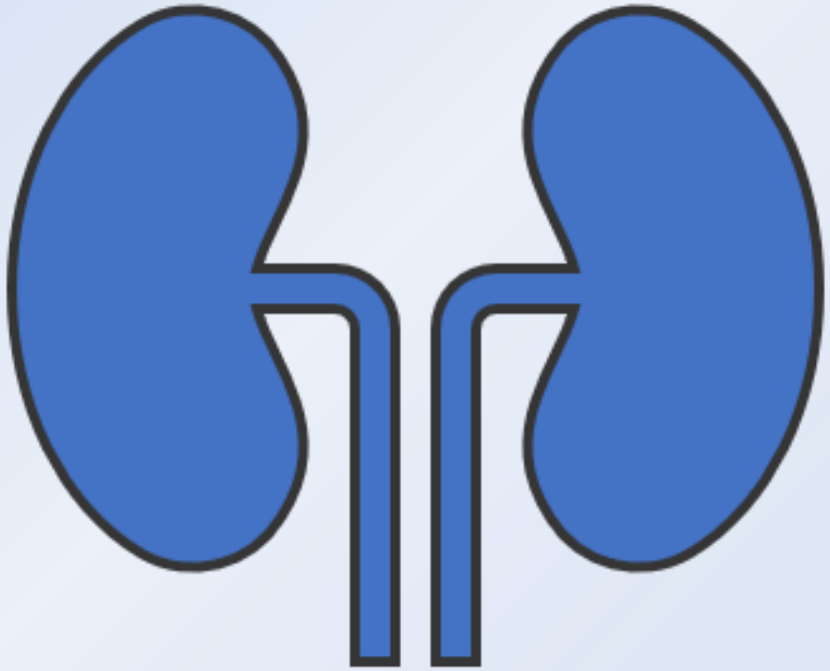
Renal anatomy



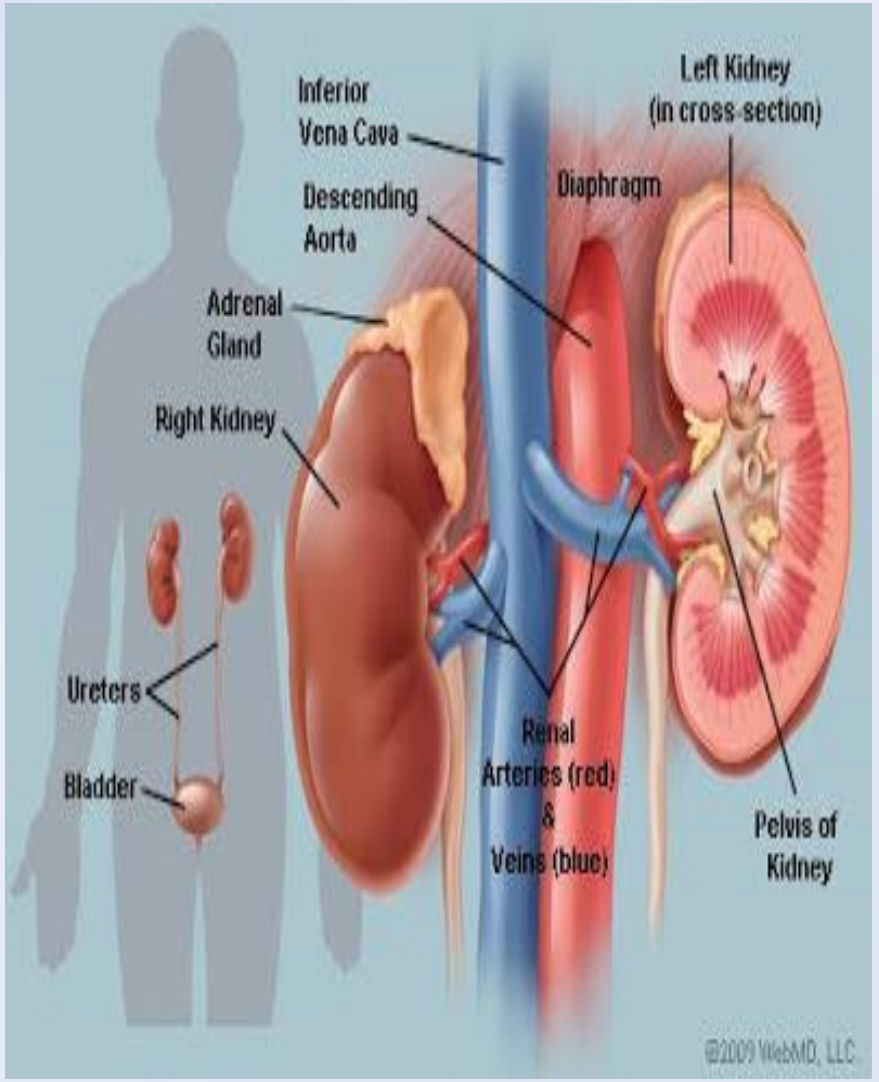
The kidneys

- Kidneys are retroperitoneal organs.
- Bean-shaped organs, reddish brown in color

- **approximately 10-12 cm long, 5 cm wide and 2.5 cm thick**

The kidneys extend from vertebral level **T12 to L3**:
upper pole → T12
Lower pole → L3
Hilum → L1

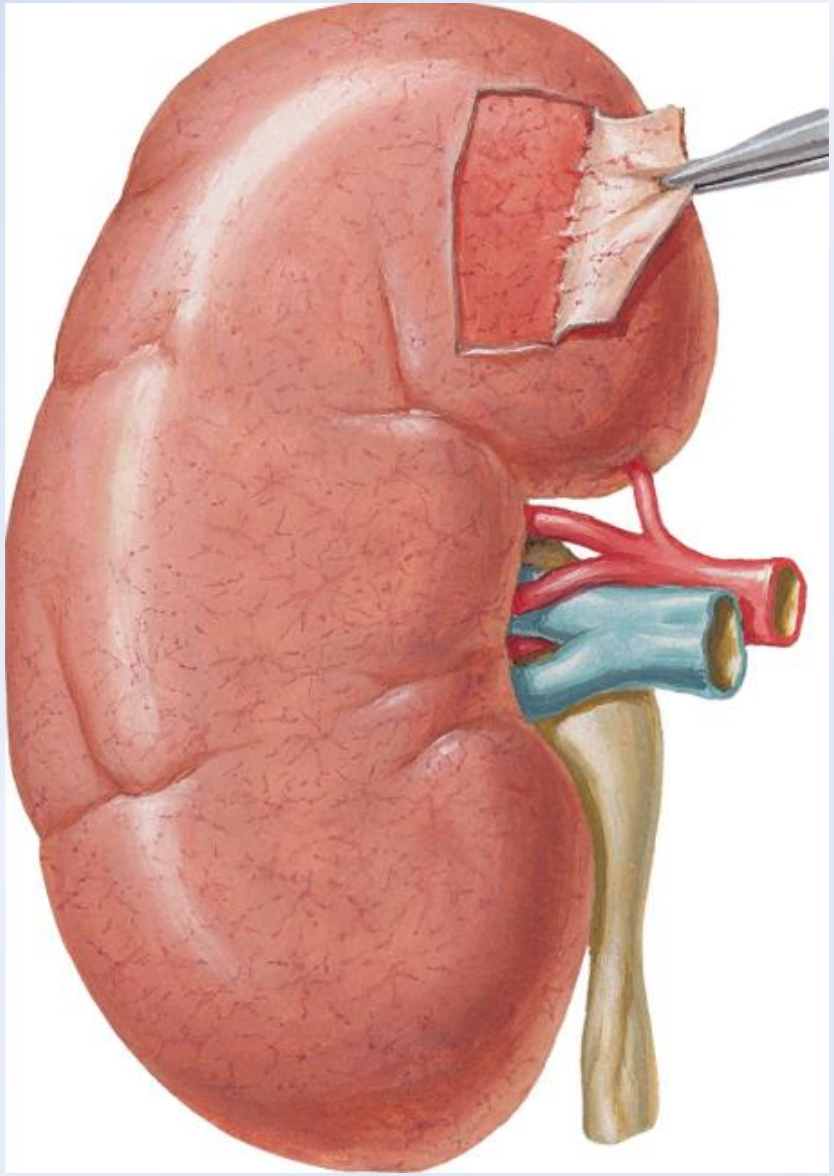
-The **right kidney** is slightly **lower** than the left because of the large size of the right lobe of the liver.



- **1. TWO poles** (upper & lower): upper pole is nearer to the midline than the lower pole.
- **2. TWO borders** (lateral & medial): the lateral is convex & the medial is concave and presents the hilum at the middle.
- **3. TWO surfaces** anterior & posterior.

The hilum transmits, from the front backward:

renal vein, renal artery, ureter, lymphatic vessels and sympathetic fibers



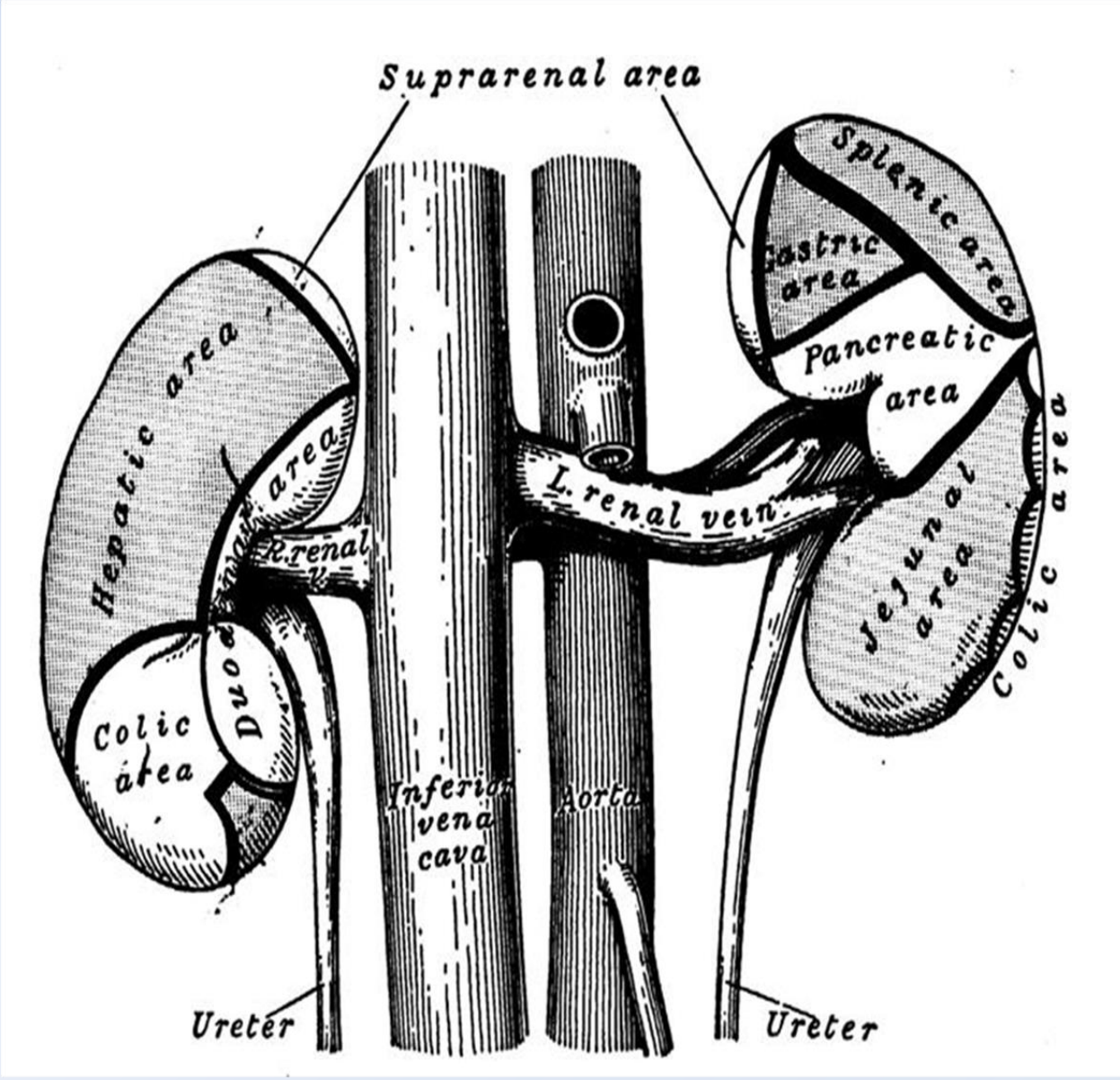
Relation

The upper pole of the kidney is covered by the suprarenal gland

. **Anteriorly**, the right kidney is related to the liver, duodenum, ascending colon or right colic flexure, and small intestine.’

The left kidney is related to the spleen, stomach, pancreas, descending colon or left colic flexure, and small intestine.

Posteriorly, the kidneys are related to rib 12 and the diaphragm, psoas major, quadratus lumborum, and transversus abdominis



Gross anatomy

- **A frontal section through the kidney reveals two distinct regions:**

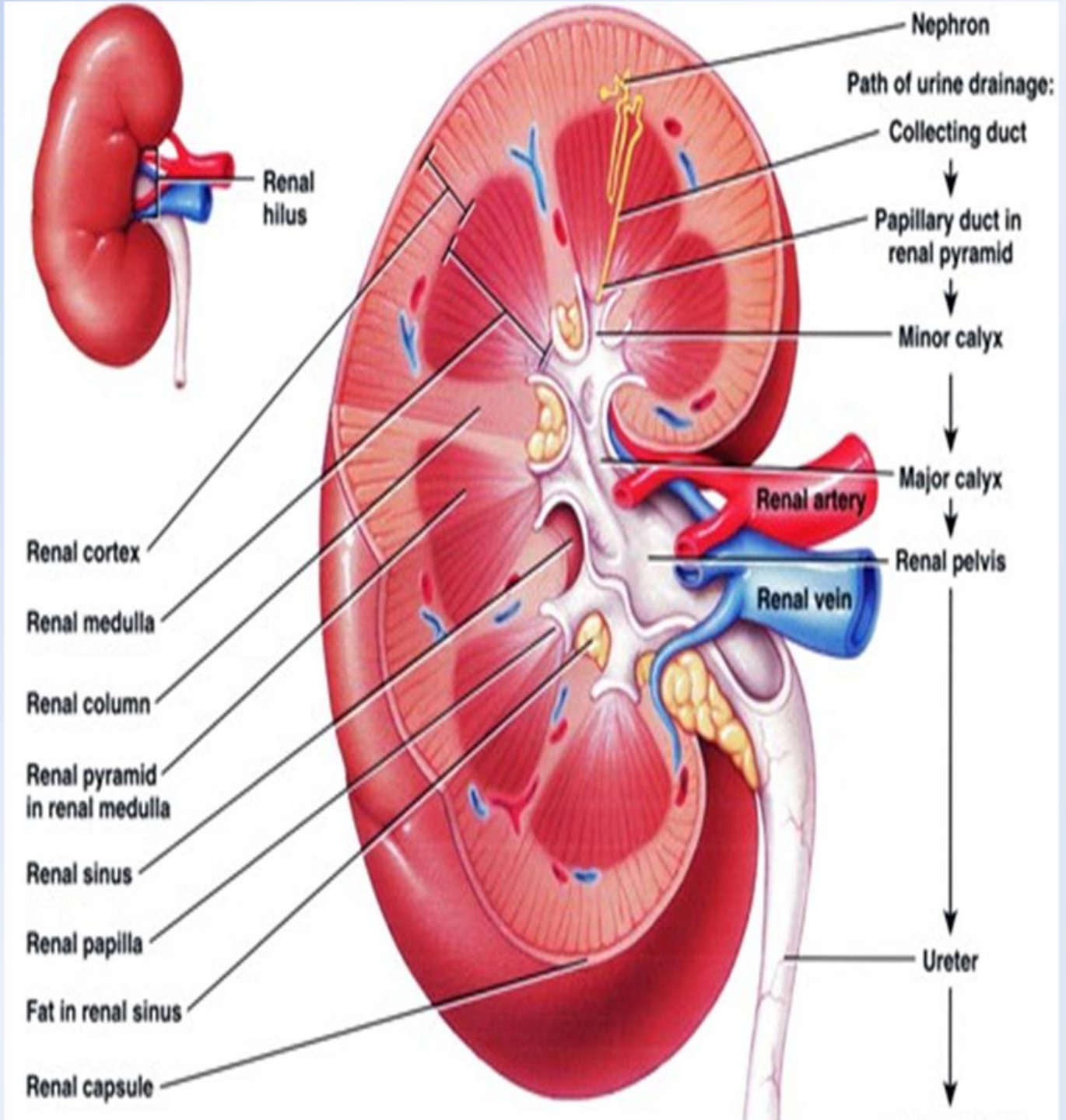
- **1) a superficial, paler area called the cortex, which is granular to the naked eye**

2) deep darker area called the medulla

The hilum of the kidney leads into a large cavity in the kidney devoid of renal tissue called the renal sinus.

-The renal sinus is occupied by the renal pelvis, (the dilated upper part of ureter).

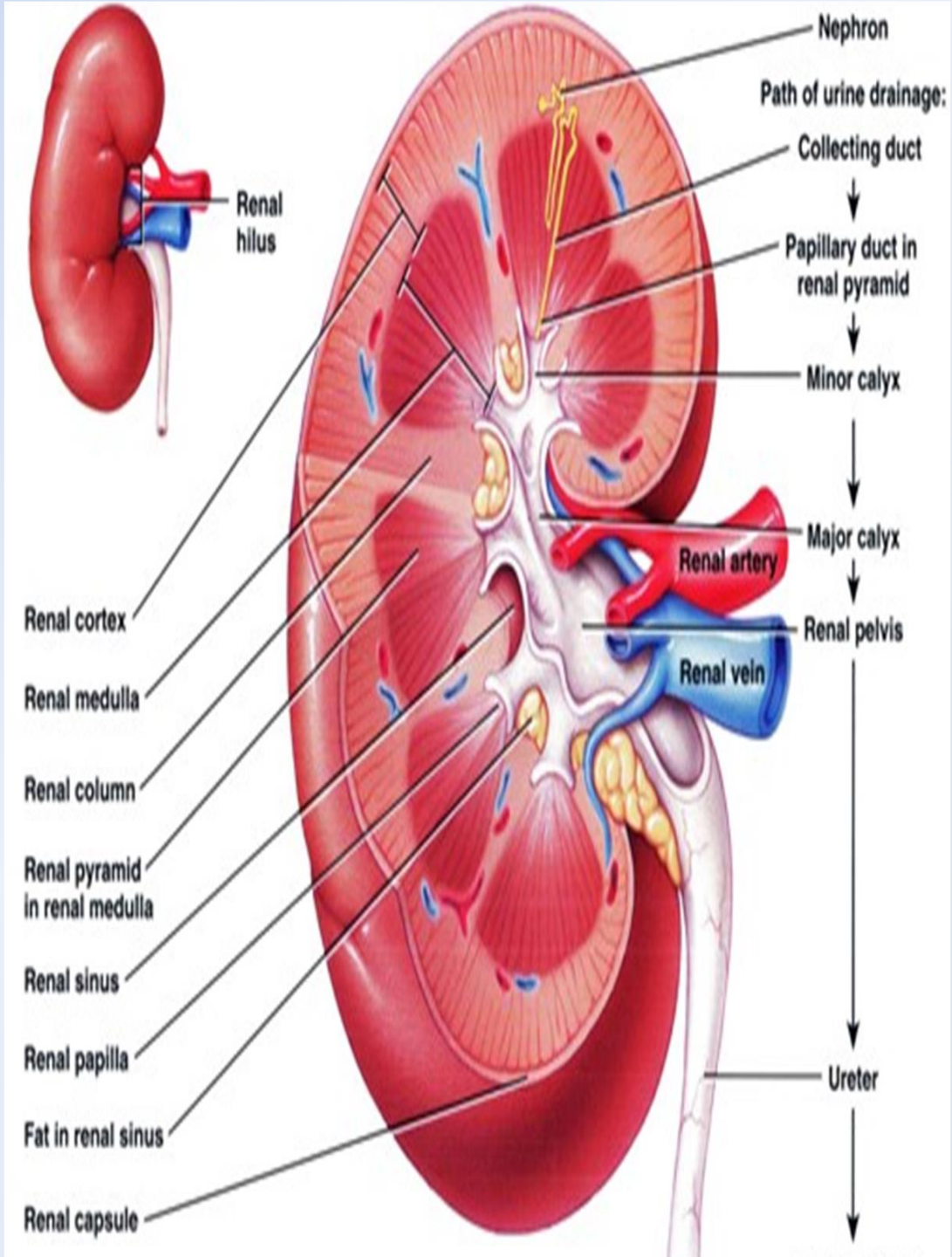
-Renal pelvis is divided into 2 – 3 major calyces, each of which divides into 2 – 3 minor calyces



The medulla is composed of about 12–20 conical masses termed the renal pyramids, each having its base oriented toward the cortex, and its apex, the renal papilla, projects medially into the interior of a minor calyx.

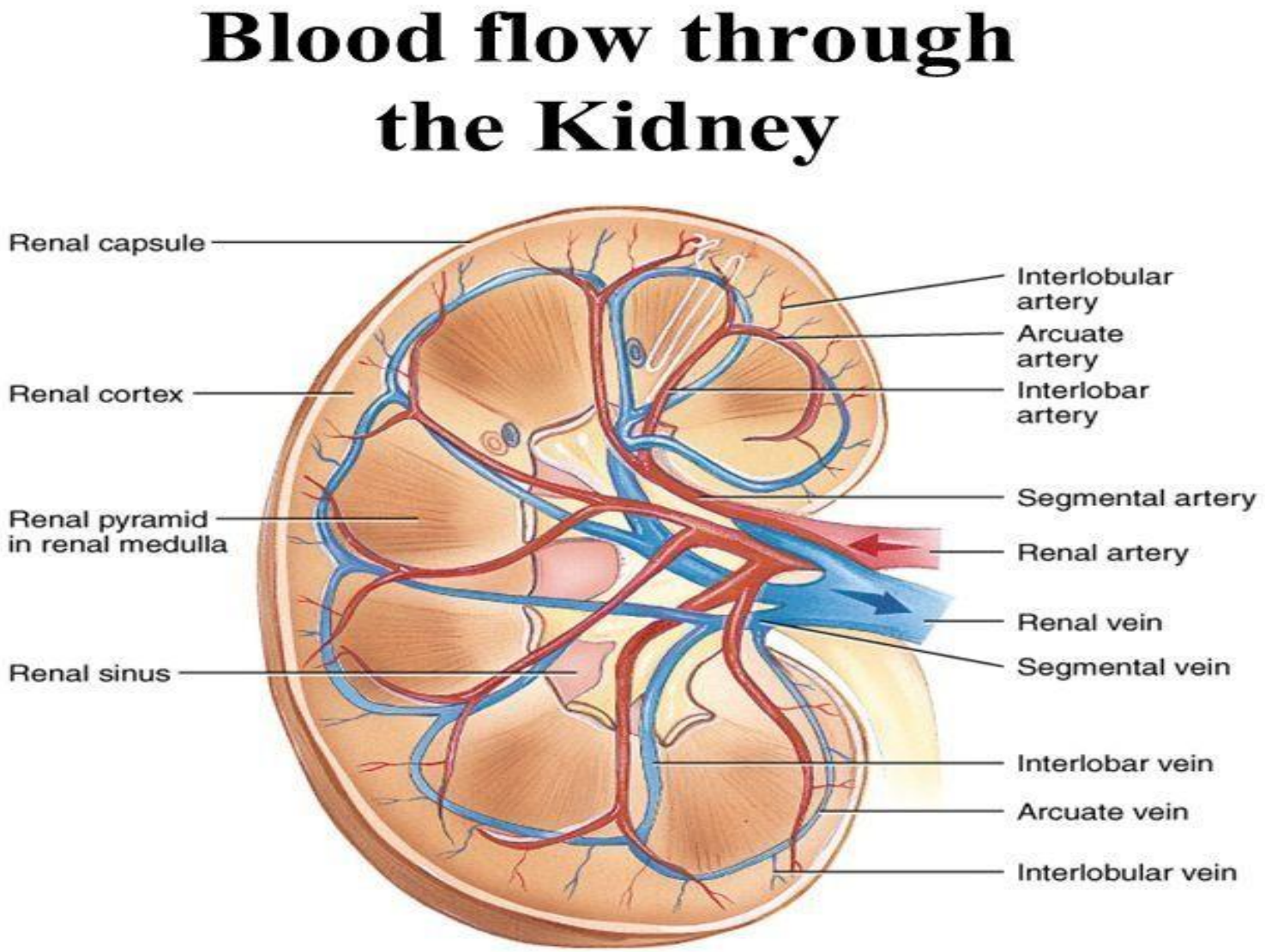
-The renal pyramids are separated by cortical tissue called the renal (cortical) column.

-The region of the cortex between the bases of the pyramids and fibrous capsule are called the cortical arches or cortical lobules.



Renal artery: Branch of descending abdominal aorta – Opposite L2 vertebra

(b) Path of blood flow



(a) Frontal section of right kidney

Nerve supply:-renal sympathetic plexus

lymph drainage:-Lateral aortic (**Lumbar**) Lymph Nodes around the origin of the kidney

nephron

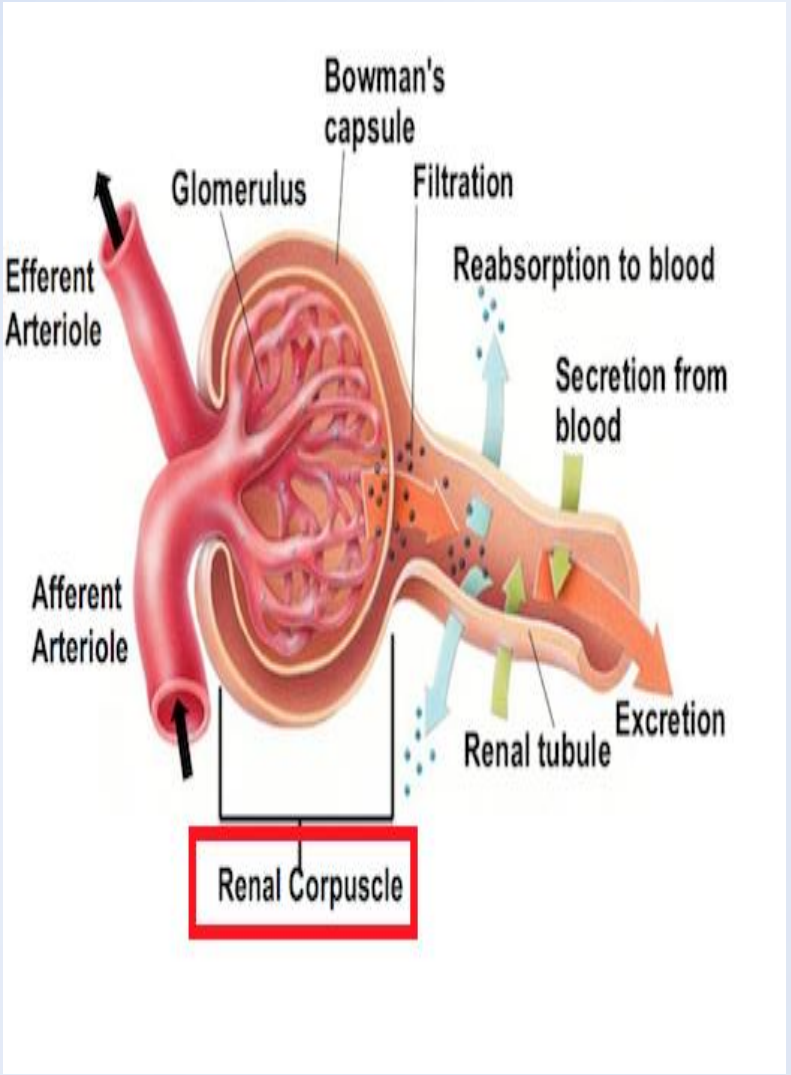
- **Functional unit of the kidney**

- almost 1-4 million nephrons per kidney

- **Consists of : 1-Renal corpuscle 2-Renal tubules**

- **Renal Corpuscle: tuft capillary + Bowman's capsule**

- **Bowman's capsule: Parietal layer + visceral layer**



Renal tubules

1)Proximal convoluted tubule

--They have a luminal brush border

-Most of the filtered fluid will be resorbed in this portion

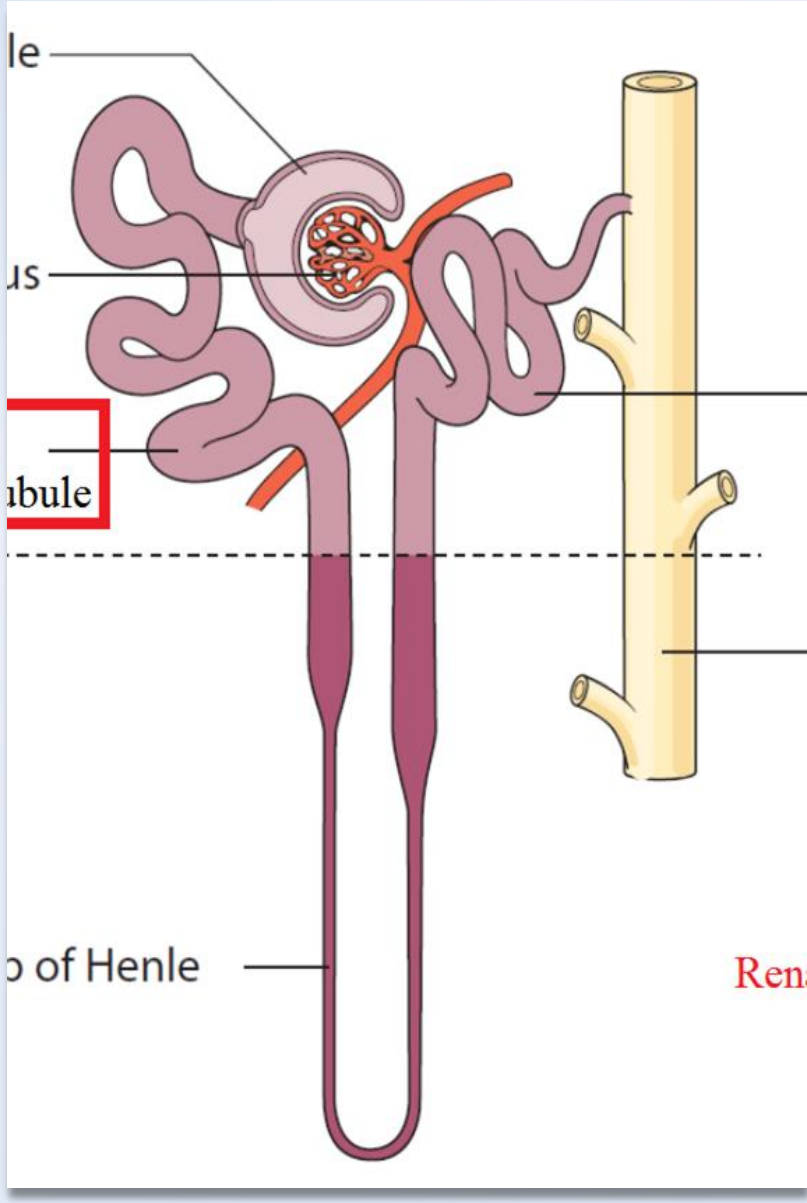
2) Henle's loop

U shaped tubule constitutes of a descending thick & thin limb and ascending thin & thick limb

3) Distal convoluted tubule

-Cells of the first coil of DCT located at the angle between afferent and efferent arterioles. → Here they become more columnar and close together and called Macula densa.

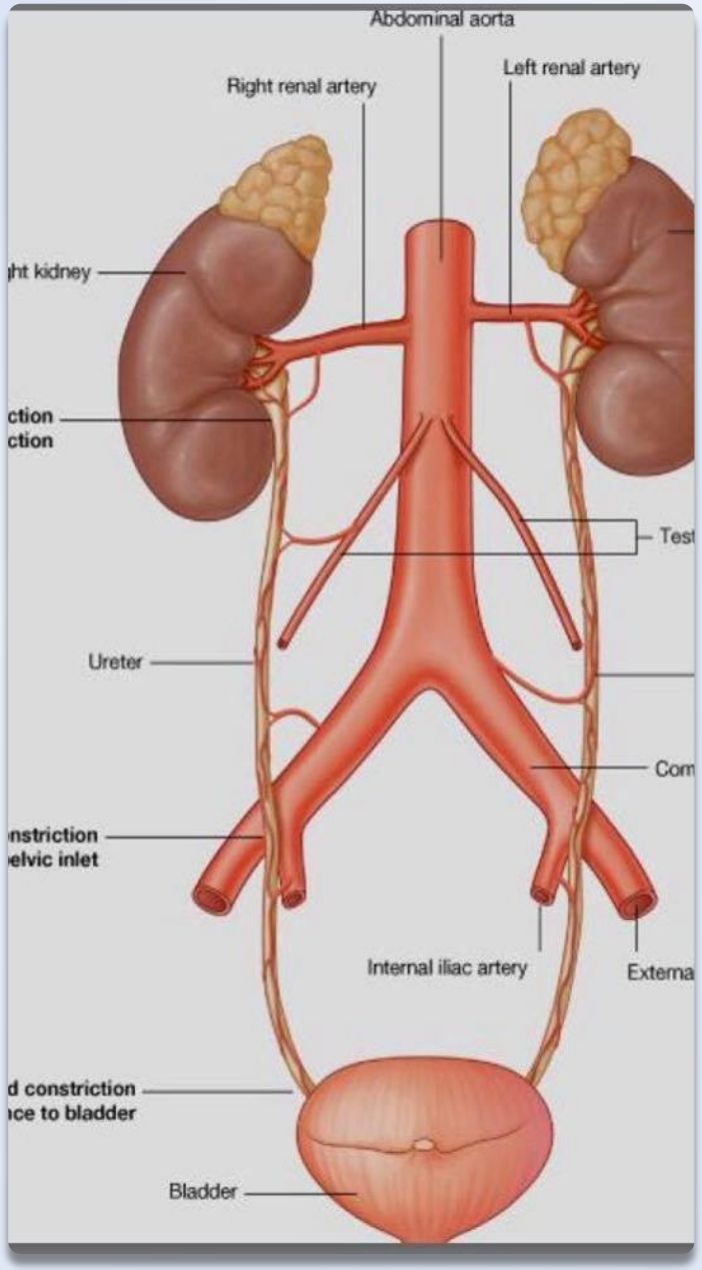
-Cells of Tunica media of afferent arterioles that lies in close contact with macula densa are called Juxtaglomerular cells.



The ureter

Retroperitoneal organ

*Each ureter is 25-30cm long and 0.5cm in diameter
-Its upper dilated part called renal pelvis
-Descends in front of the psoas major
-Crosses bifurcation of common iliac artery
-And Brim of pelvis to enter lesser pelvis
-Then, descends on lateral pelvic wall until ischial spine
-After which they turned forward and medially to reach base of bladder.
-Penetrates posterior wall of bladder and runs obliquely through that wall of about 2 cm before opening into lumen of bladder.



Blood supply:

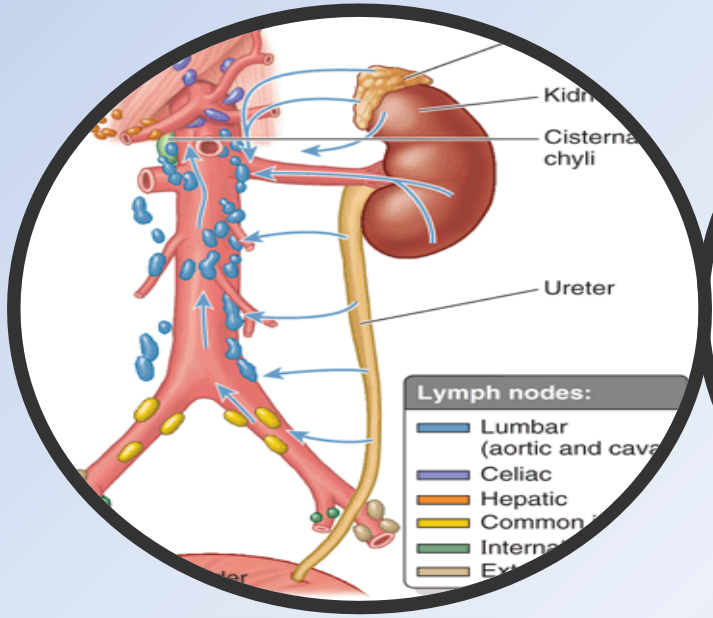
Upper part → renal vessels
Middle part → gonadal vessels
Lower part → superior vesical vessels

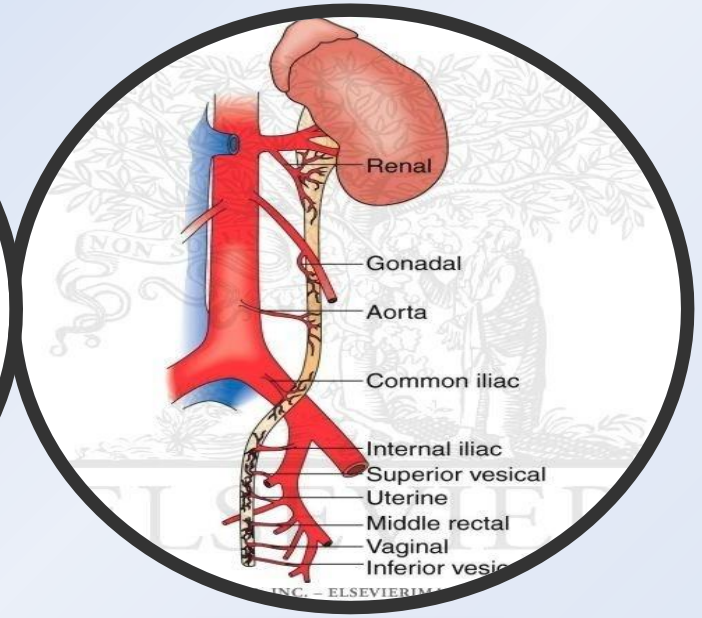
Lymph Drainage:

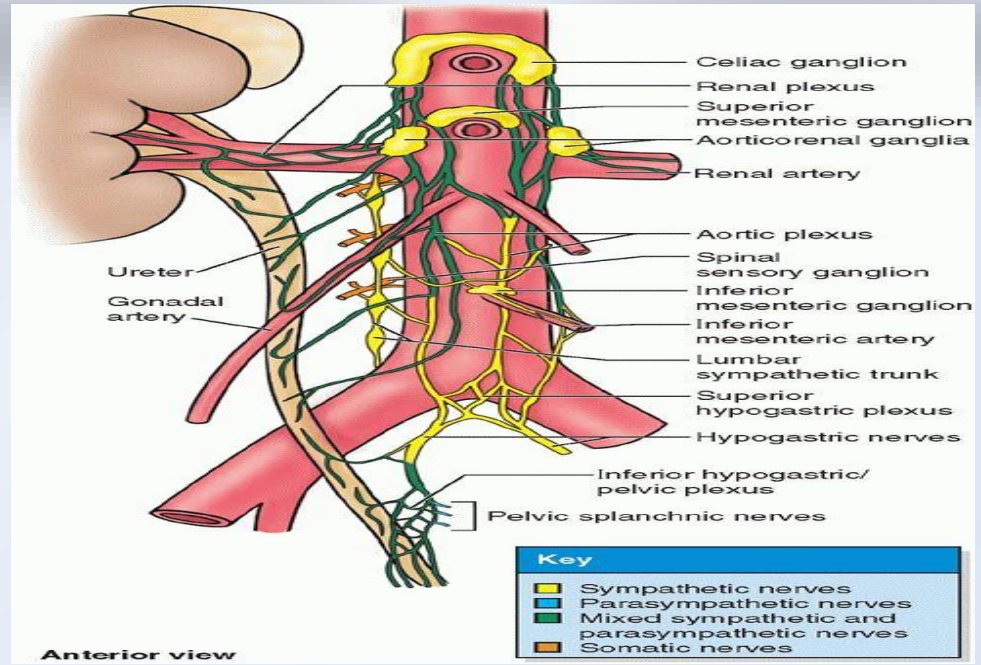
to lateral aortic and iliac lymph nodes

Nerve supply of the ureter

Abdominal part: Renal & gonadal plexuses.
***Pelvic part**: Sup. & inf. Hypogastric plexuses.
***Visceral afferent fibers**: Enter the spinal cord at segment T11 & 12 and L1 & 2.







The bladder

The bladder is pyramidal in shape, located within the pelvic cavity, immediately behind pubic bones.

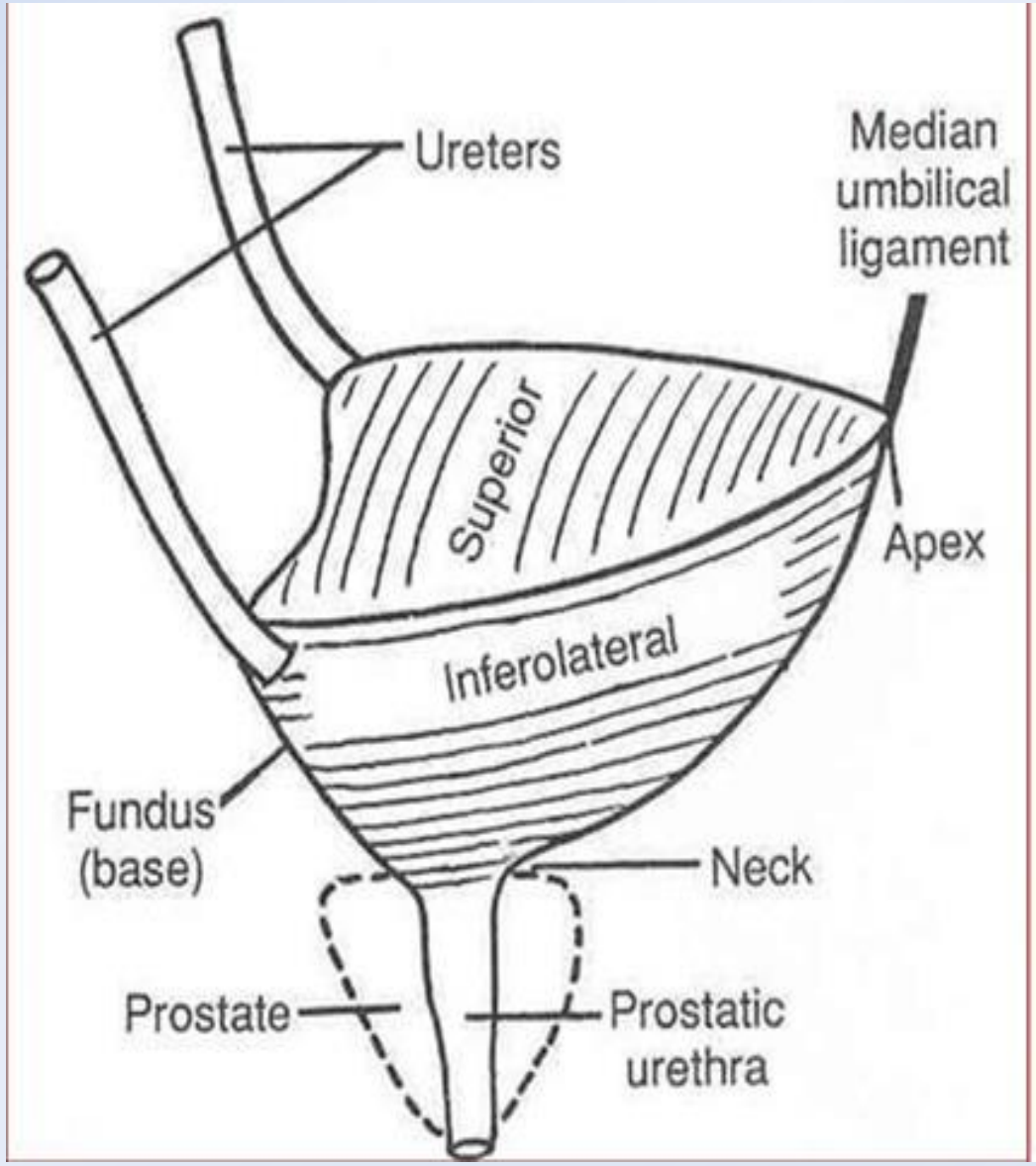
- The superior wall of a distended bladder may rises up into hypogastric region.
- Maximum capacity is about 500 ml

it consists of:

An apex: Lies at junction of upper end of anterior border and anterior angle of superior surface. It is connected to umbilicus by median umbilical ligament .

,A base(Posterior Surface),A superior Surface, 2 inferolateral Surface.

Neck: Lowest region of bladder



The trigone of the bladder

- A smooth mucous membrane that covers internal surface of base of bladder

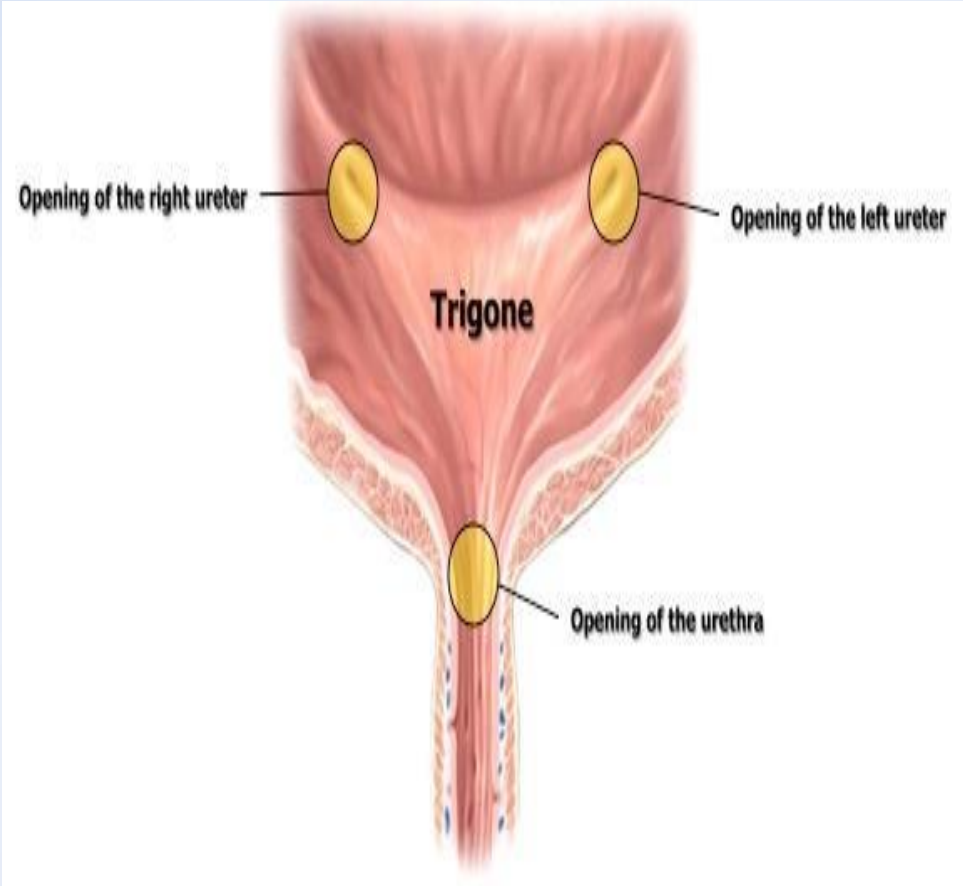
- has :
- 1- Two posterolateral angles :

contain the two ureteral opening;

- 2- Anteromedian angle :

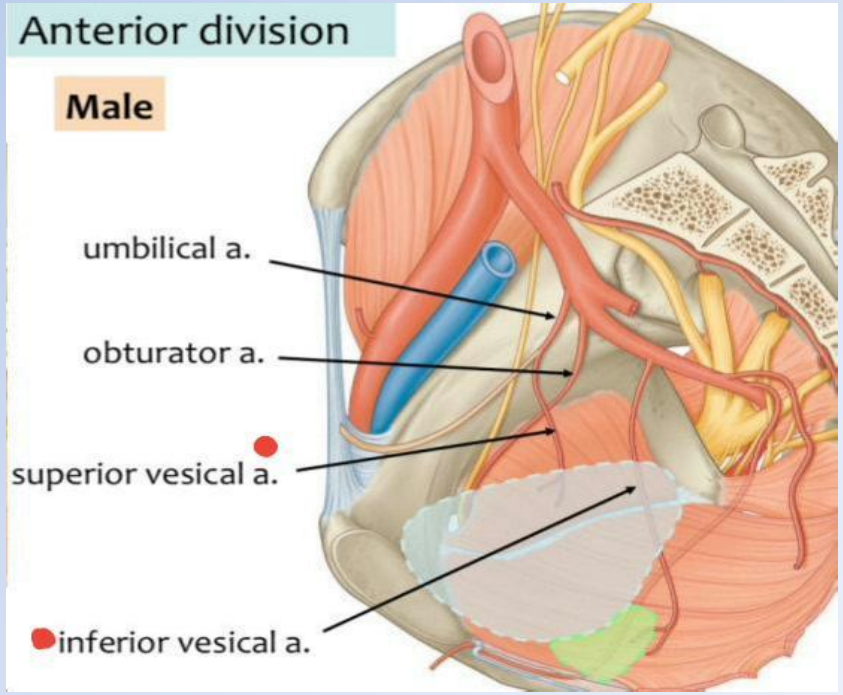
the opening of the urethra

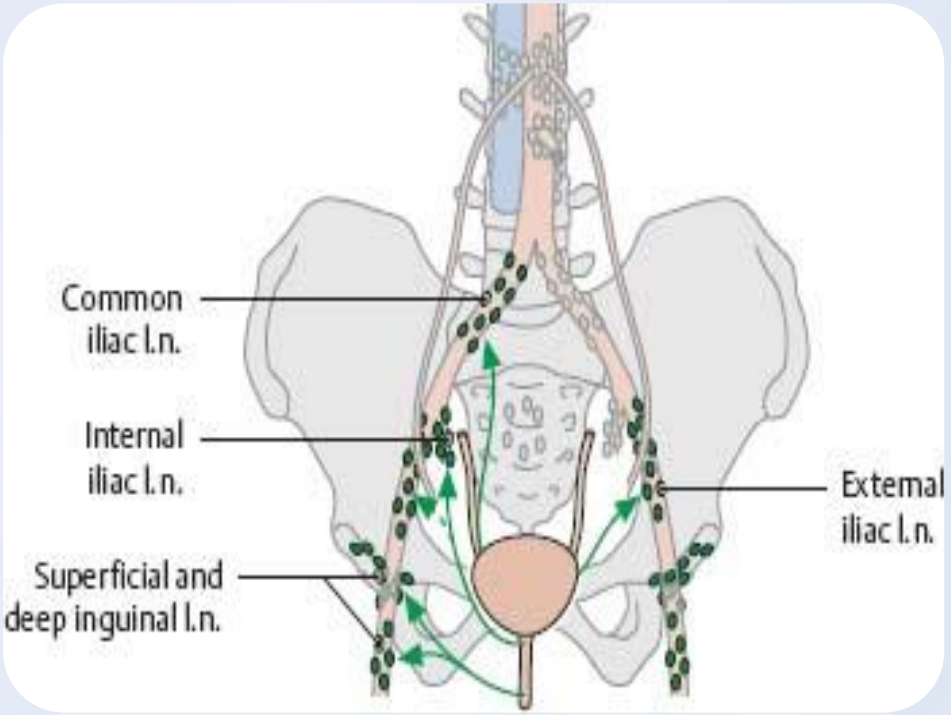
(internal urethral opening)



Blood supply of the bladder

- Arterial : Superior and inferior vesical arteries.
- Venous : form a complicated venous plexus on the inferolateral surface called Vesical venous plexus, which drains into internal iliac vein.
- Lymph Drainage: Drains into the internal and external iliac LN

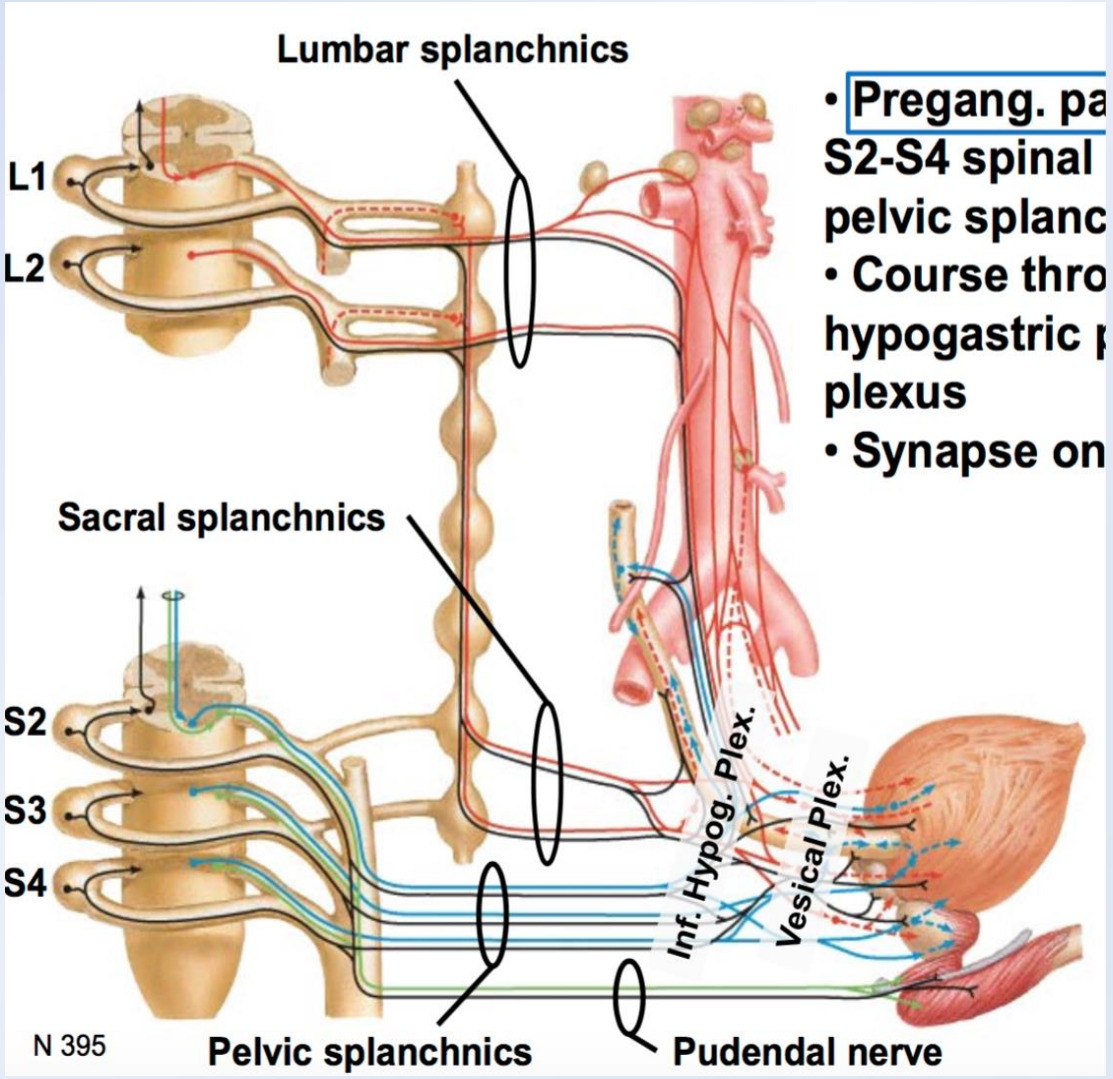




Nerve supply

3 types of nerve fibers

1) Sympathetic nerve fibers
2) Parasympathetic nerve fibers
3) Visceral nerve fibers



Evaluating Kidney Function

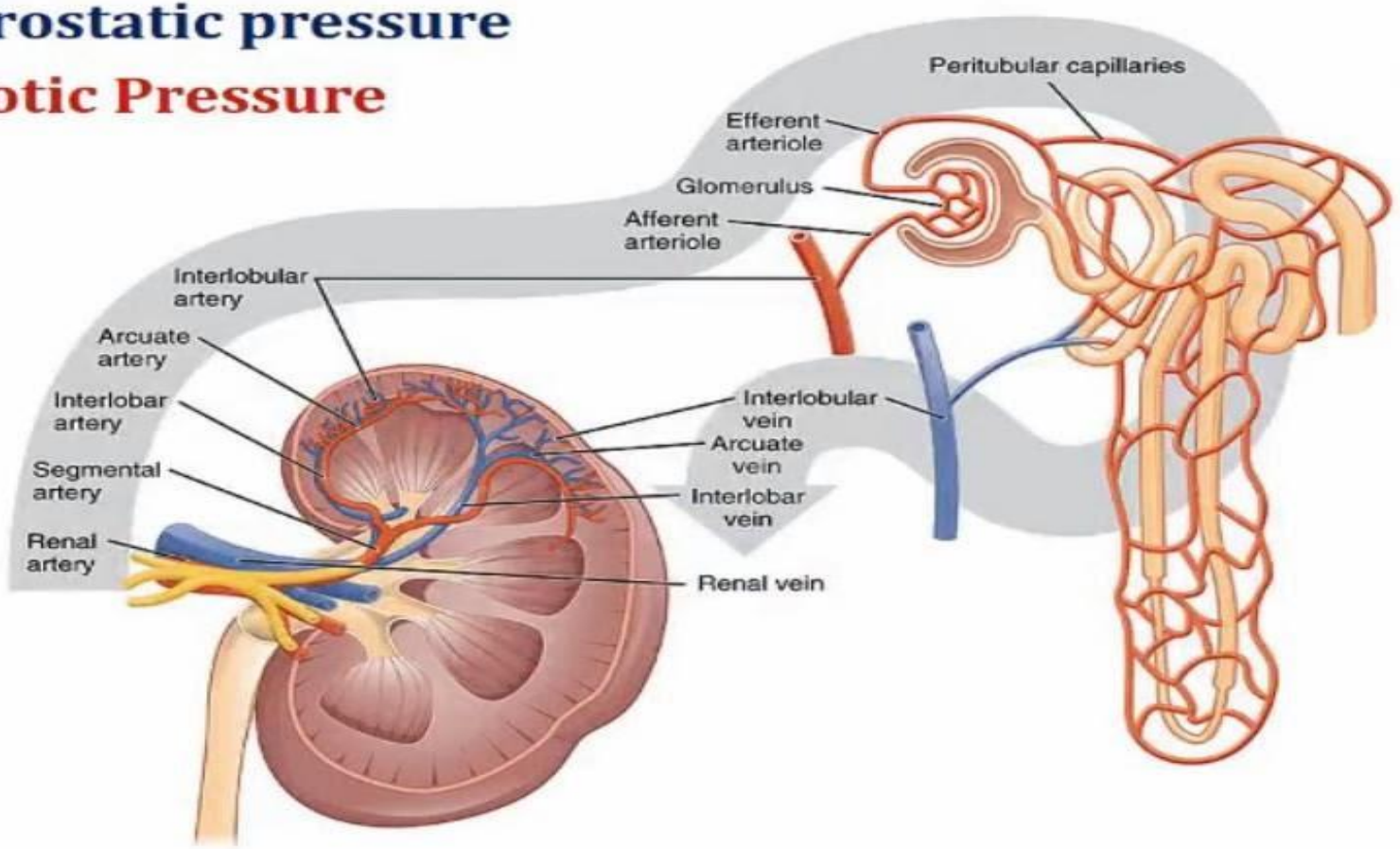
- **Glomerular filtration rate**
  - How much liquid passes through the filter (i.e. glomerulus)?
  - Determined from plasma, urine measurements
  - GFR falls as kidneys fail
- Renal Blood/Plasma Flow
  - How much blood enters kidney
- Filtration Fraction
  - GFR/RPF

Measuring GFR

- Theoretical determination
  - Need to know pressures in capillary, Bowman's capsule
- Clinical determination
  - Need to know plasma concentrations solutes, urine flow

Theoretical Determination GFR

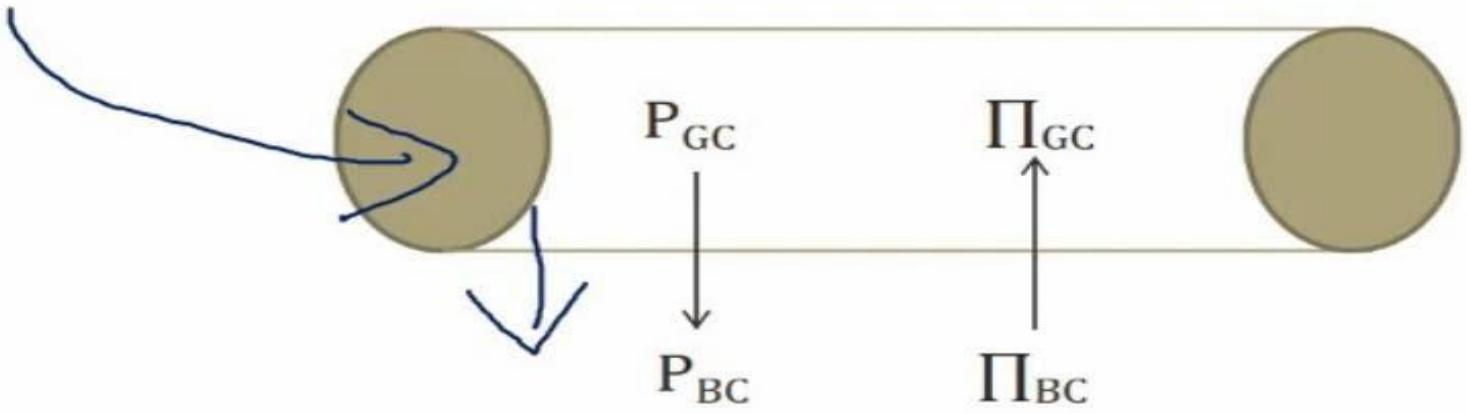
- Filtration Driving Forces
  - **Hydrostatic pressure**
  - **Oncotic Pressure**



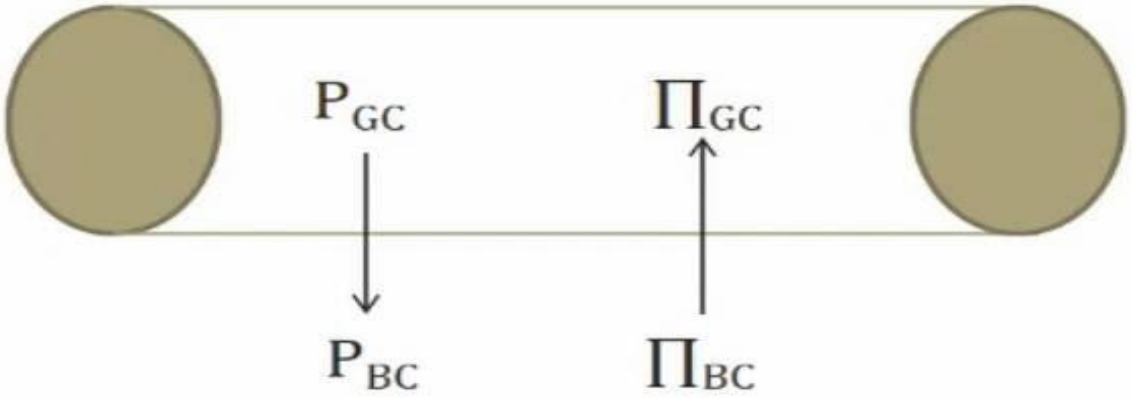
OpenStax College/Wikipedia

Capillary Fluid Exchange

- **Hydrostatic pressure** – fluid PUSHING against walls
  - High pressure drives fluid TOWARD low pressure
- **Oncotic pressure** – concentrated solution PULLING fluid in
  - High pressure draws fluid AWAY from low pressure



Glomerular Filtration Rate



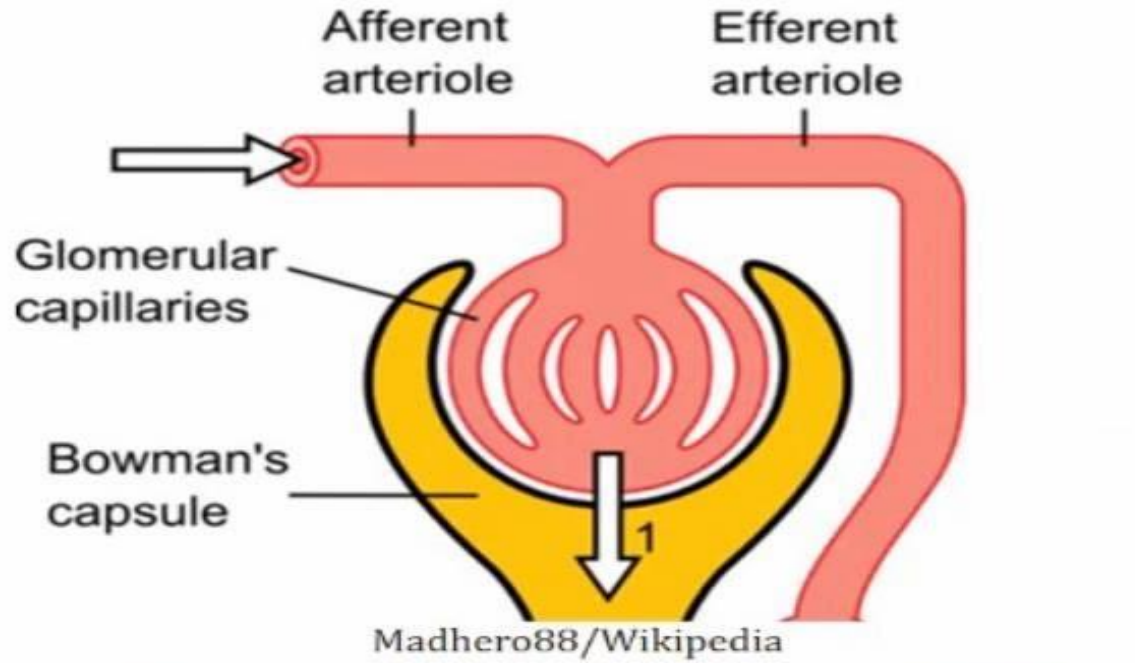
To change GFR:

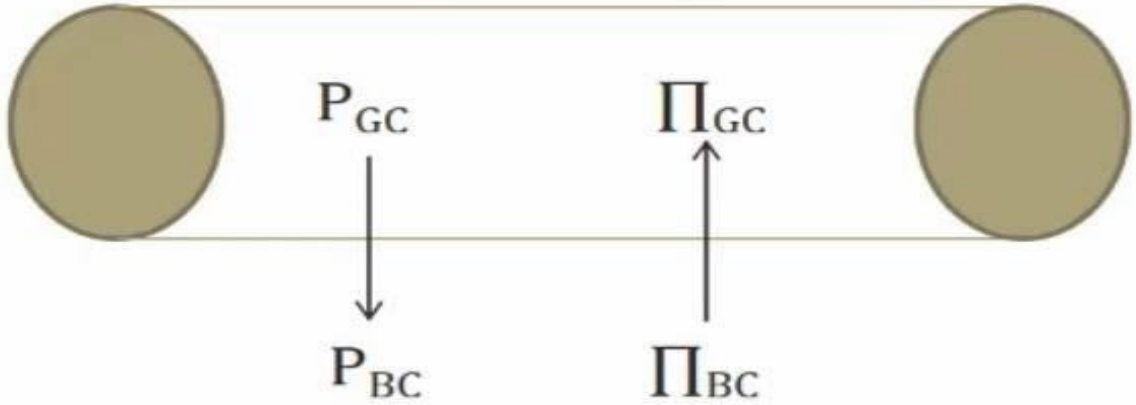
Change P_{GC} or P_{BC}

Change Π_{GC} or Π_{GC}

Arterioles

Efferent & Afferent

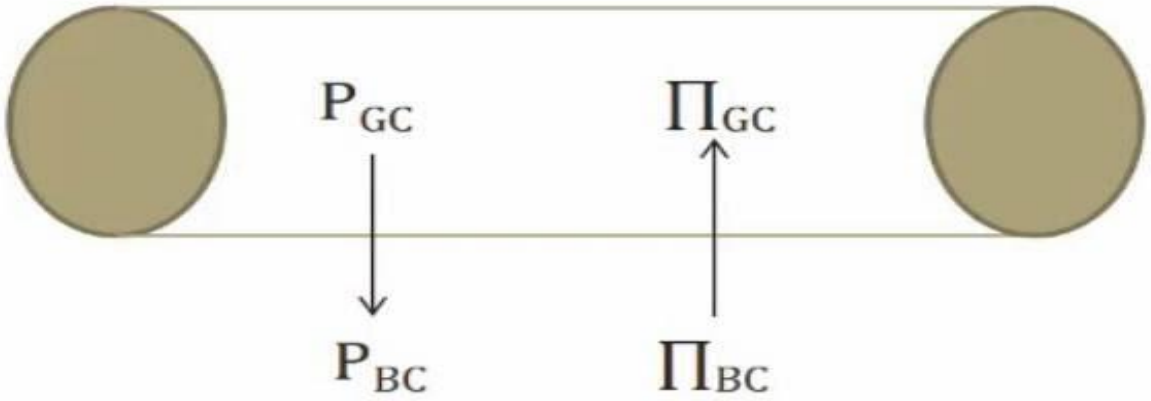




Raise P_{GC}

Increase GFR

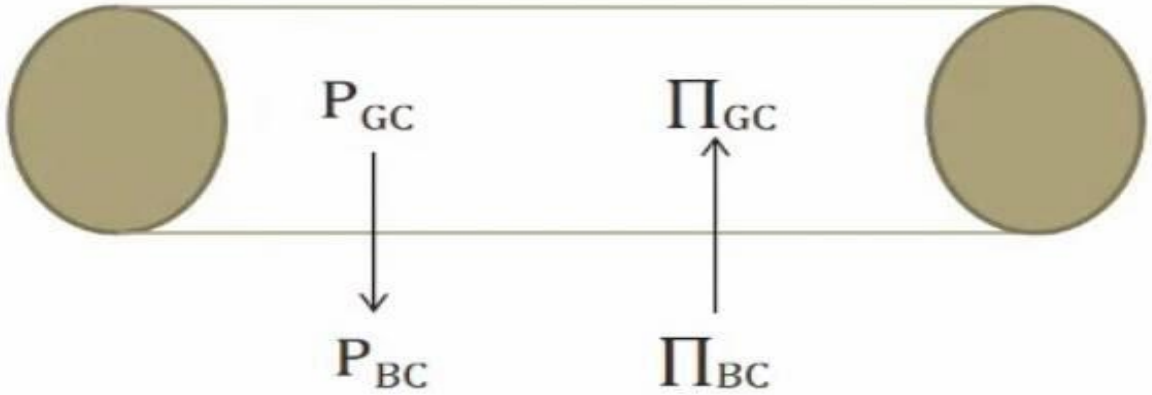
- **Dilate afferent arteriole**
  - More blood IN
  - Increase RPF
  - Increase P_{GC}
  - Increase GFR
  - No change FF



Raise P_{GC}

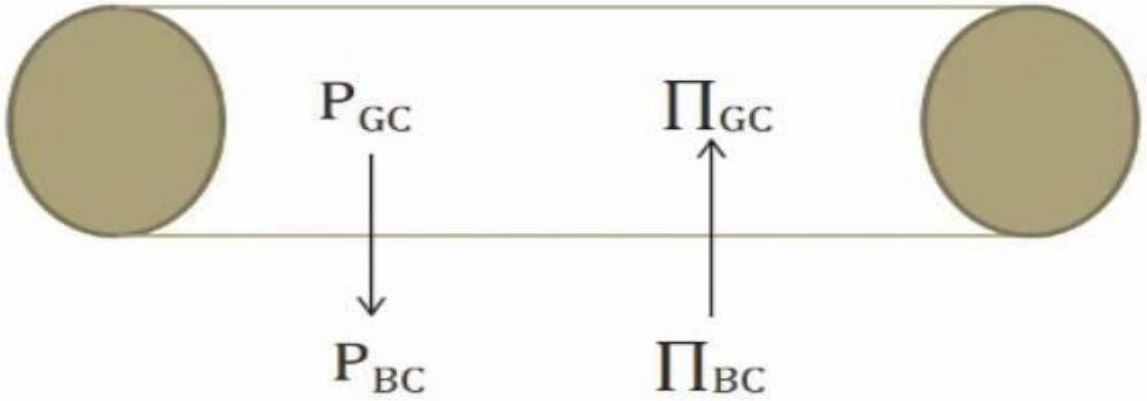
Increase GFR

- **Constrict efferent arteriole**
  - Blood backs up behind constricted arteriole
  - Less blood out
  - Decreased RPF
  - Increase P_{GC}
  - Increase GFR
  - Increase FF



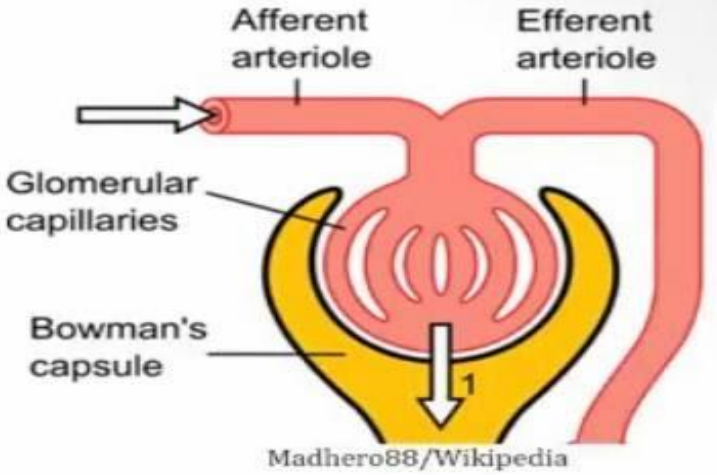
Raise Π_{GC}

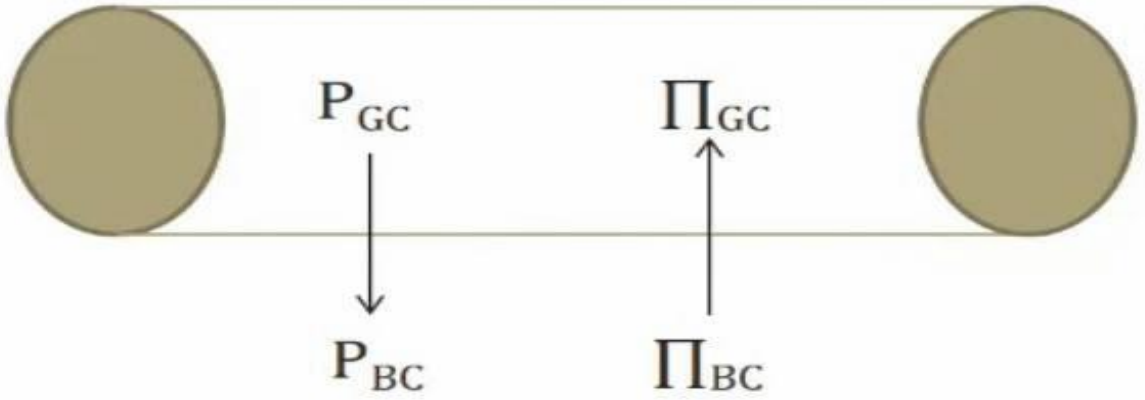
- **Increase protein levels in blood**
  - Less blood drawn into proximal tubule
  - Lower GFR
  - No change RPF
  - Decrease FF



Change P_{BC}

- **Obstruct ureter → Increase P_{BC}**
  - Urine backs up behind obstruction
- Less GFR P_{BC}
- No effect RPF
- Decrease FF



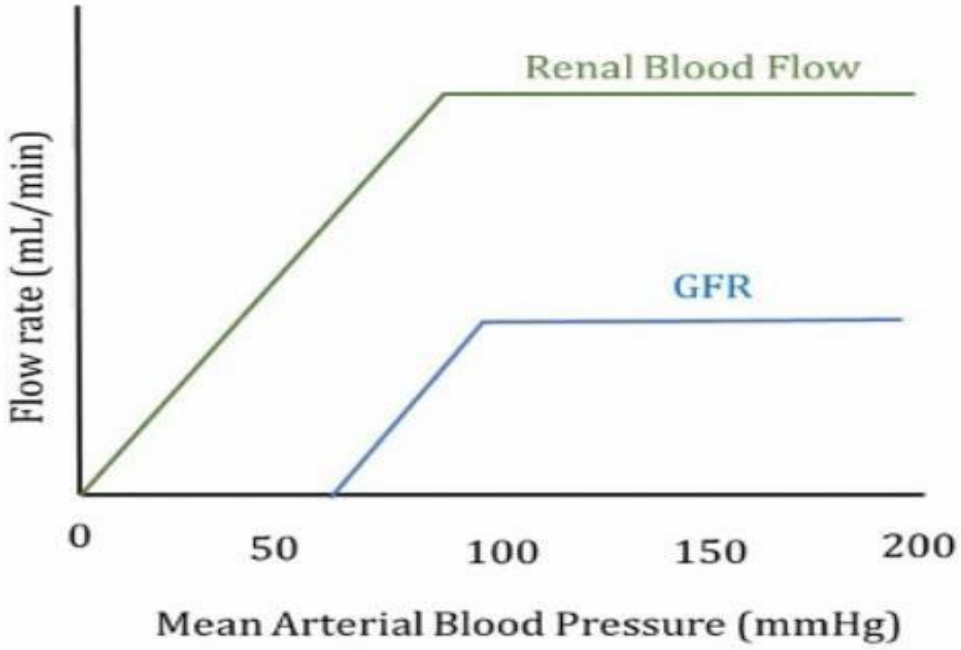


Glomerular Flow Dynamics

	RPF	GFR	FF
Afferent Dilation	↑	↑	--
Efferent Constriction	↓	↑	↑
↑ plasma proteins	--	↓	↓
Ureter obstruction	--	↓	↓

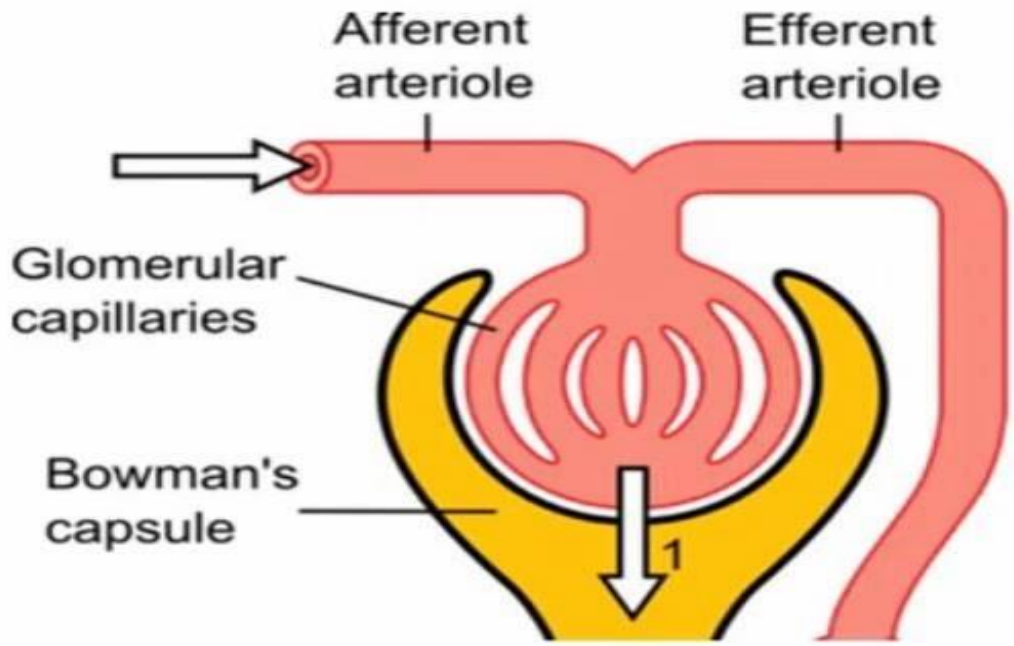
Autoregulation

- Constant GFR/RBF over range of blood pressures
- #1: Myogenic mechanism
- #2: Tubuloglomerular feedback



Myogenic Mechanism

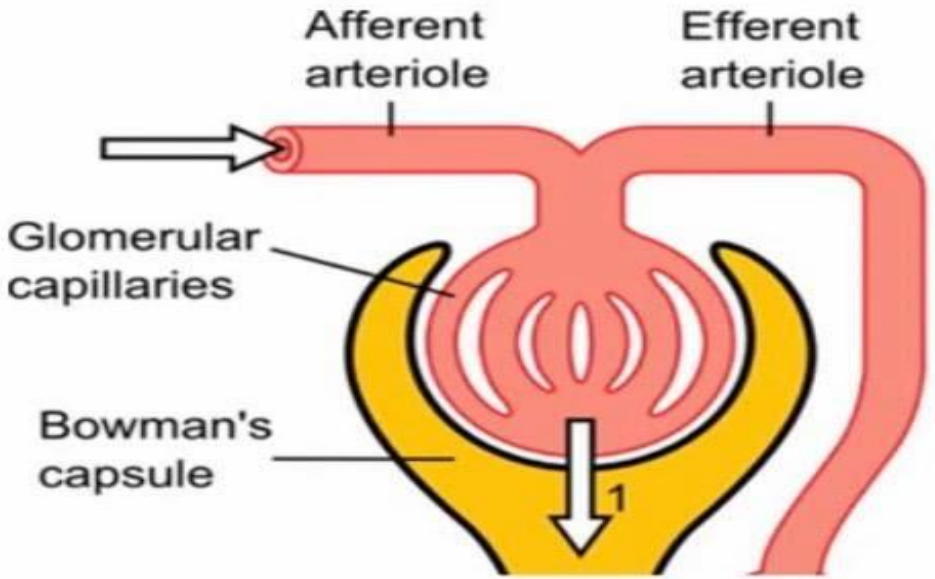
- **Afferent arteriole constricts with high pressure**
  - Responds to changes in stretch
- Result is maintenance of normal GFR/RPF



Madhero88/Wikipedia

Tubuloglomerular Feedback

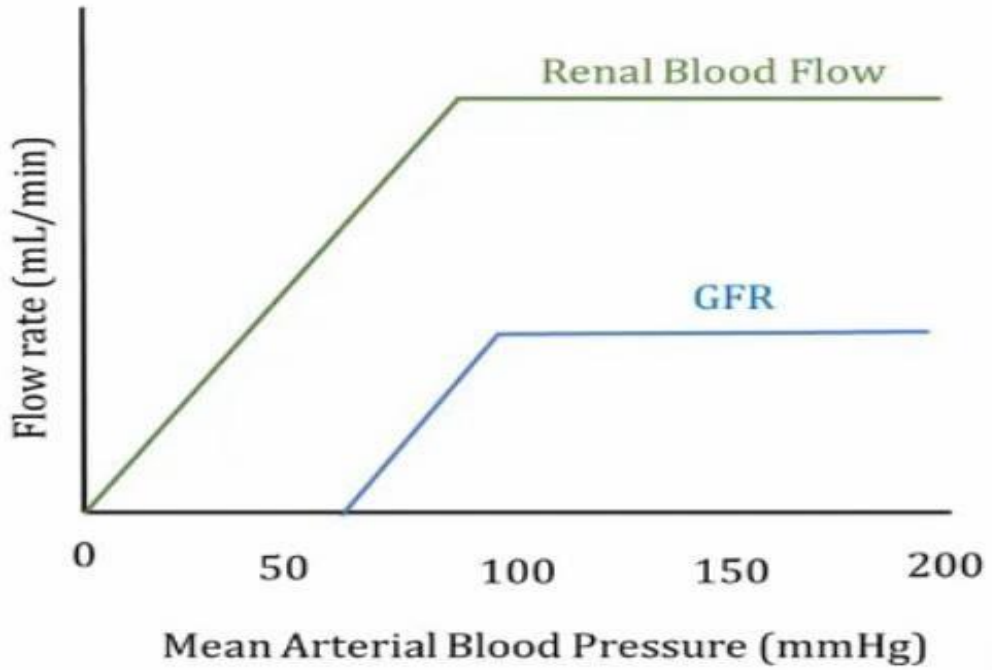
- ↑ urinary flow in tubule → ↑ NaCl to distal tubule
- NaCl sensed by **macula densa** (part of JG apparatus)
- Macula Densa → **vasoconstriction afferent arteriole**



Madhero88/Wikipedia

Severe Volume Loss

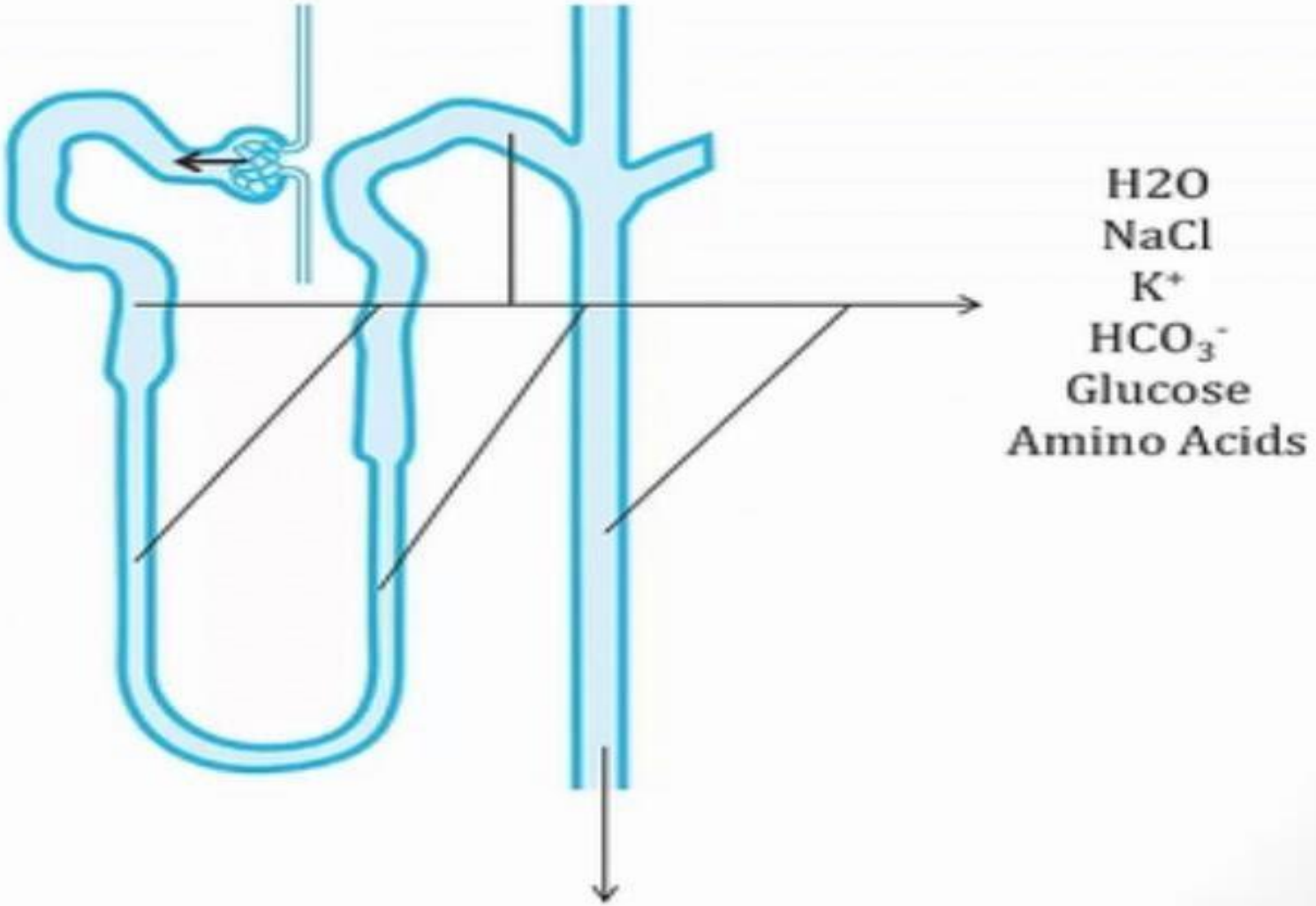
- Profound loss of fluid (vomiting, diarrhea, etc.)
- Renal plasma flow falls significantly
- **Auto-regulatory mechanisms overwhelmed**
- ↓ GFR
- ↑ BUN/Cr
- Pre-renal failure



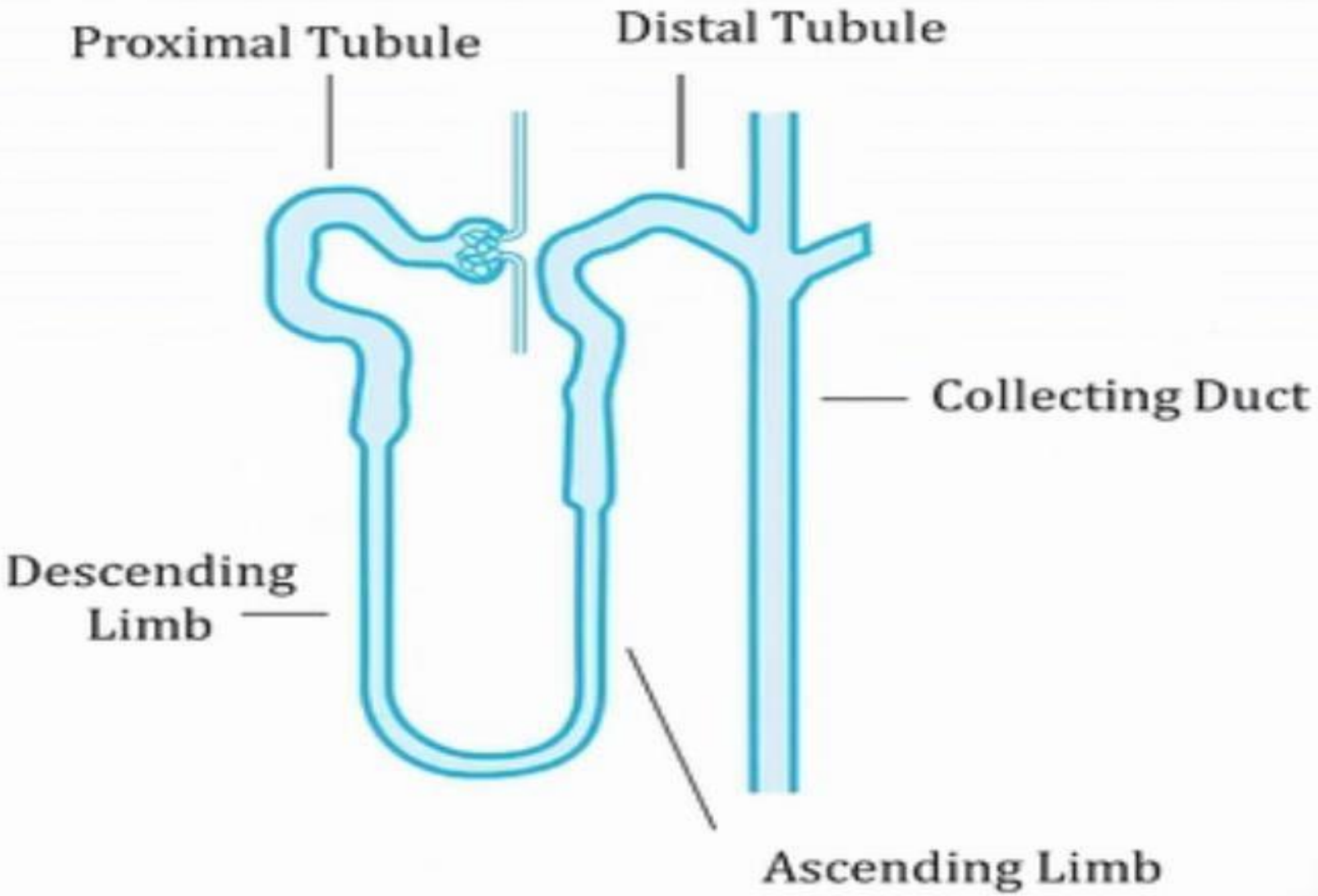
Nephron Physiology

Jason Ryan, MD, MPH

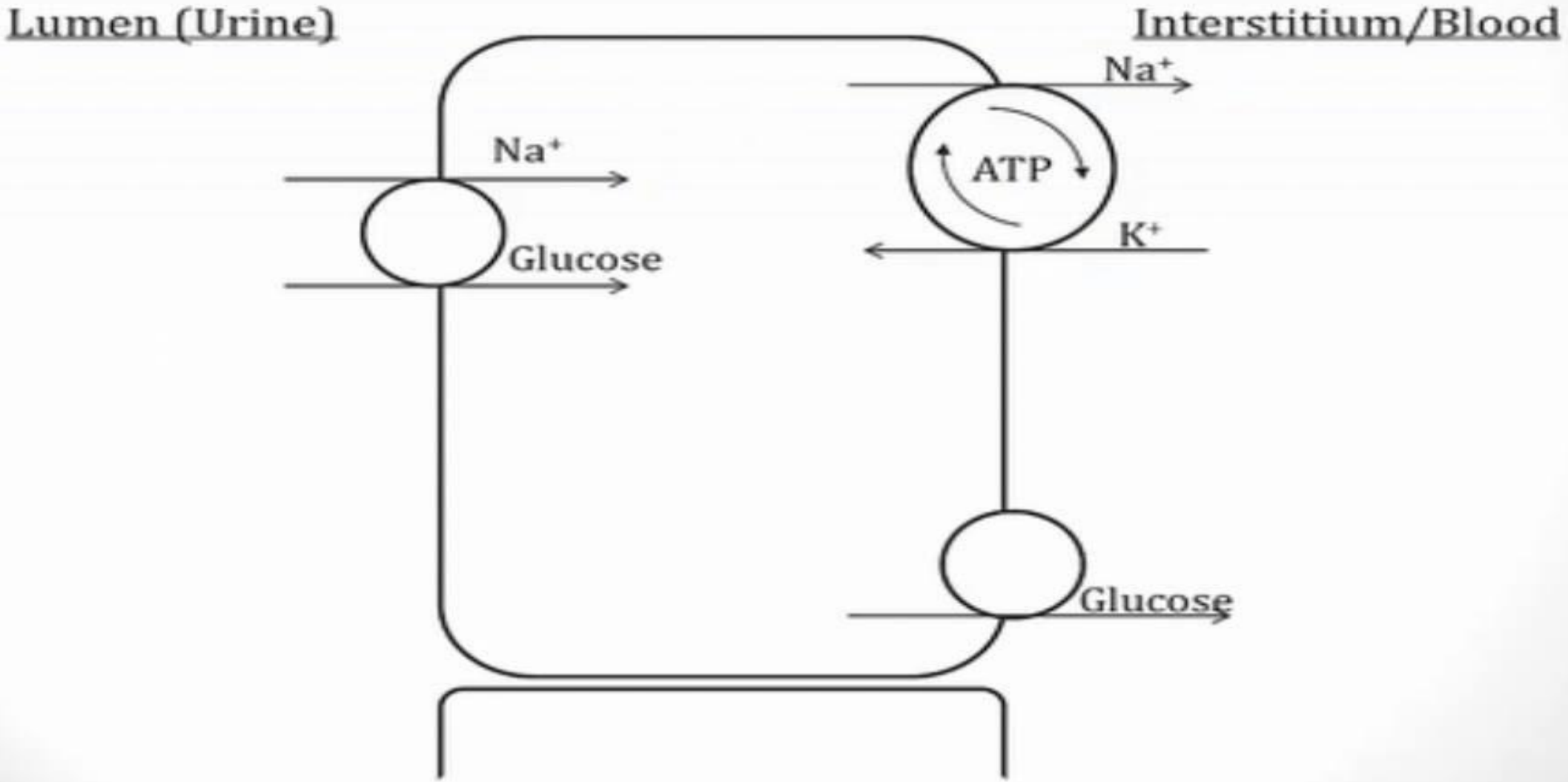
Nephron



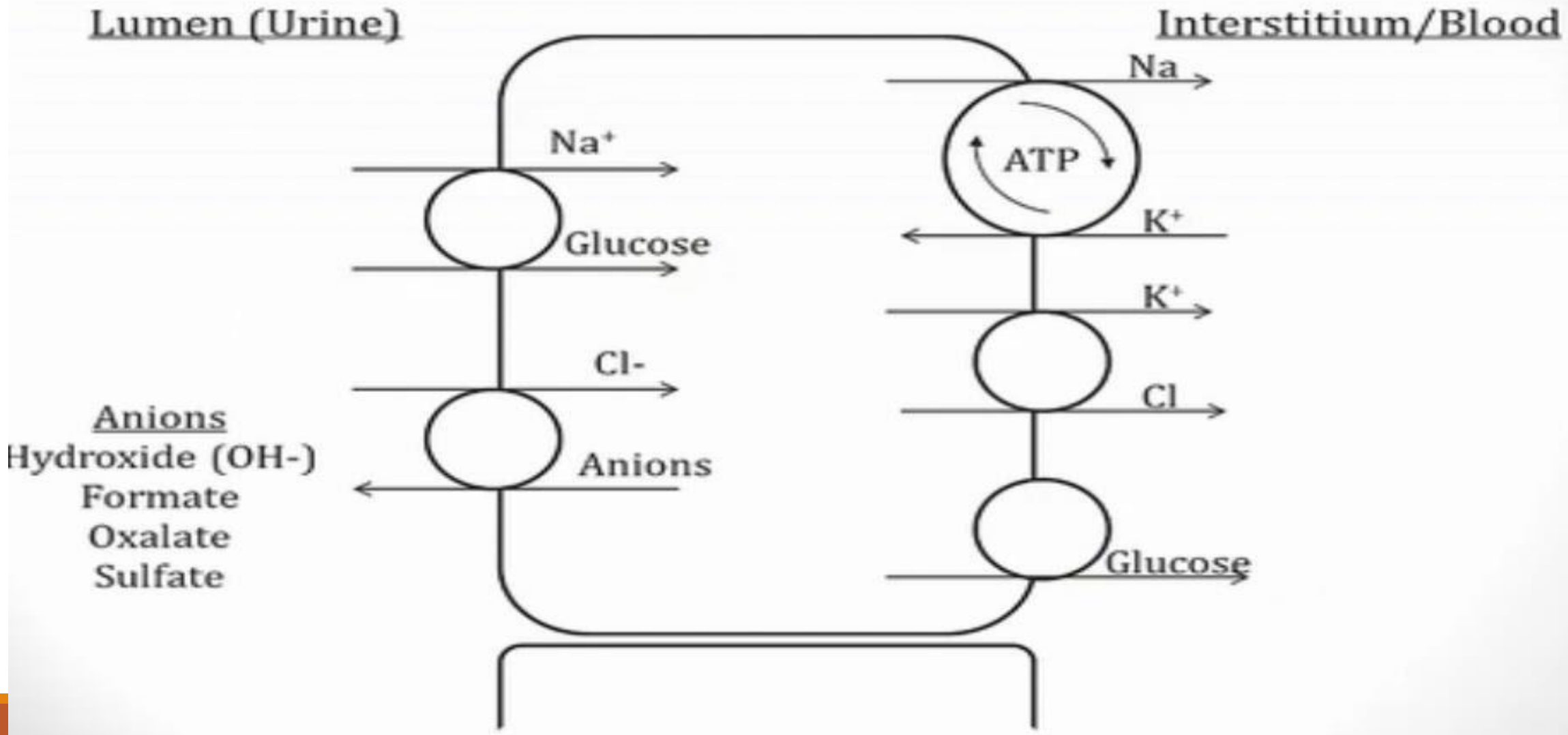
Segments of Nephron



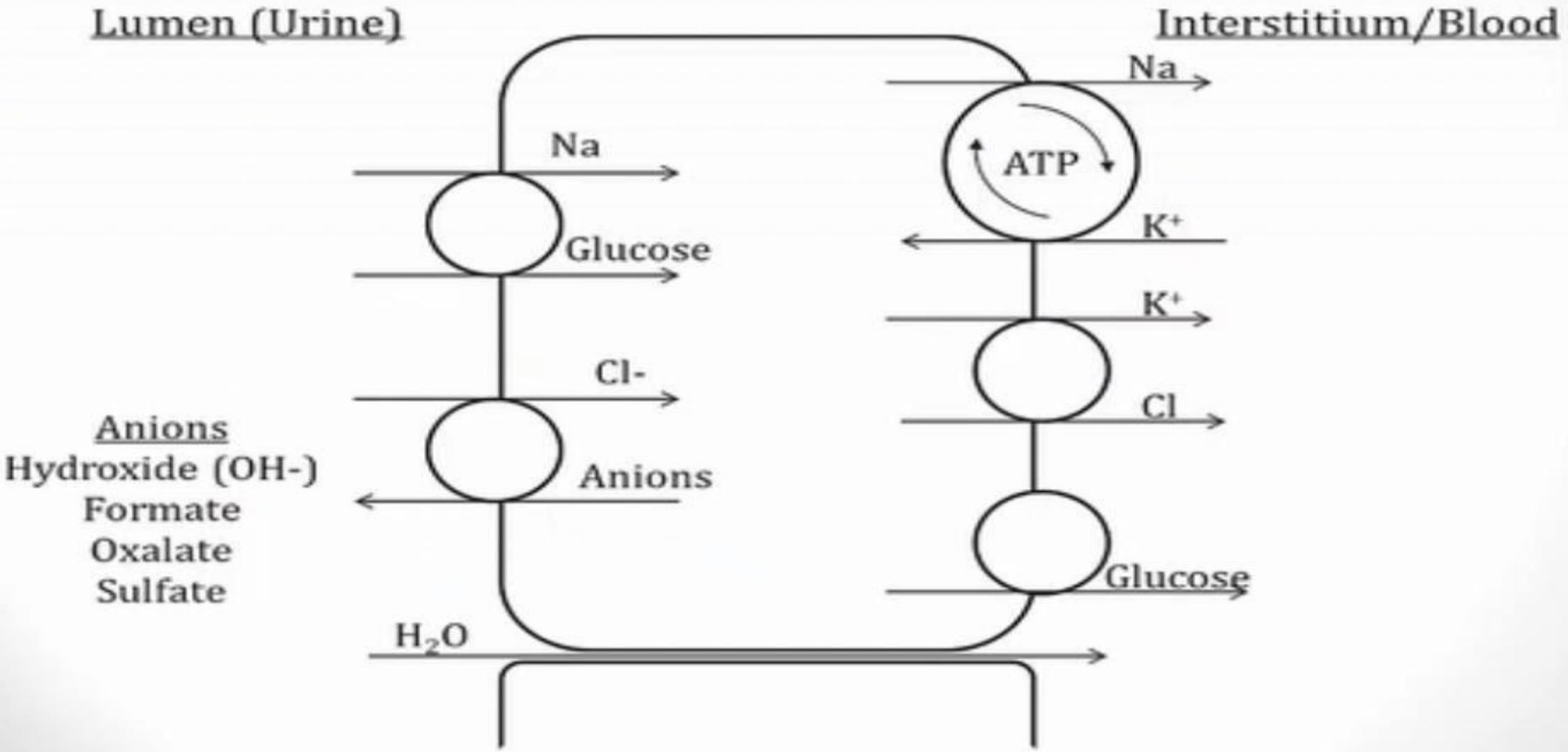
Proximal Tubule



Proximal Tubule



Proximal Tubule



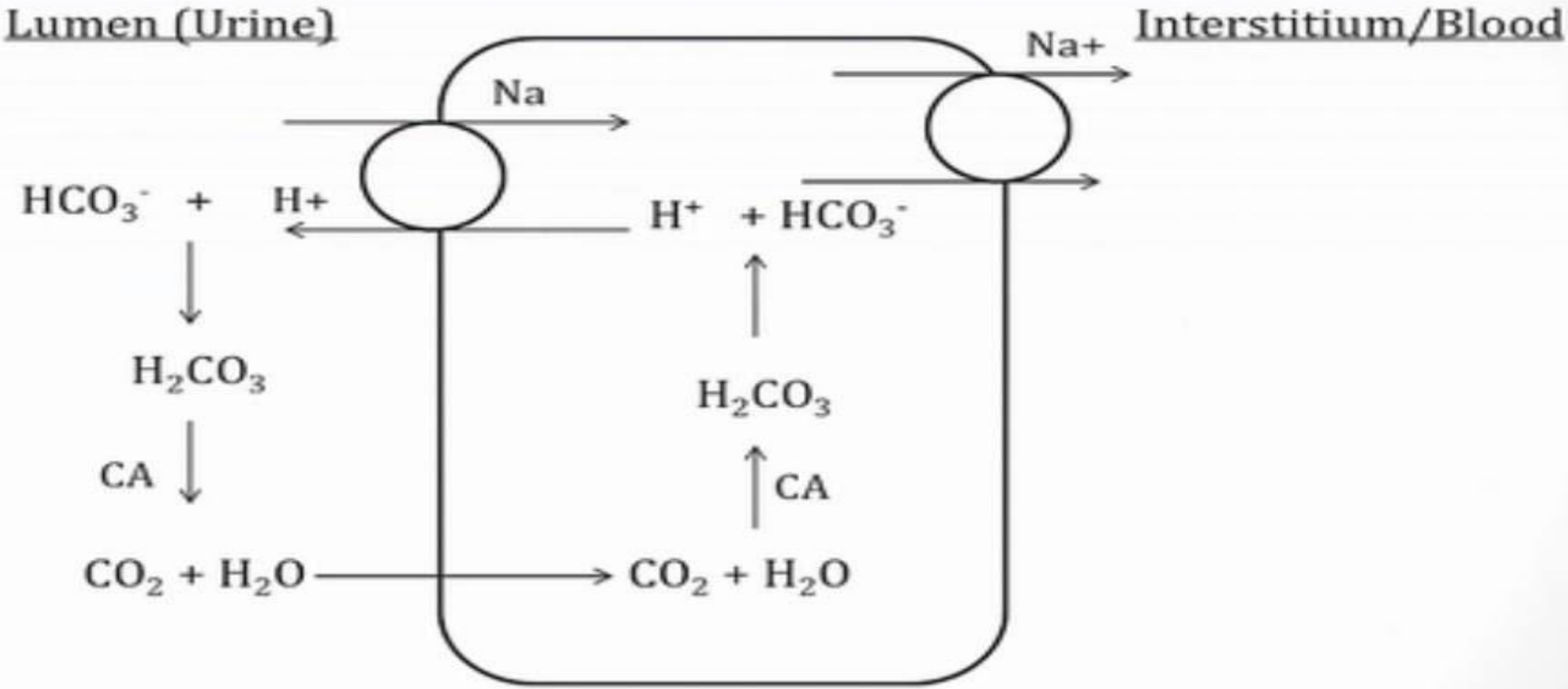
Glucose Clearance

- Completely reabsorbed proximal tubule
- Na/Glucose co-transport
- At glucose ~160mg/dl → glucose appears in urine
- Glucose ~350mg/dl → all transporters saturated
- Diabetes mellitus = "sweet" diabetes
- In pregnancy, ↓glucose reabsorption
- Some glucosuria normal

Amino Acid Clearance

- Na/AA transporters in proximal tubule reabsorb all amino acids
- Hartnup disease
  - No tryptophan transporter in proximal tubule
  - Amino acids in urine
  - Skin rash resembling pellagra (plaques, desquamation)

Proximal Tubule: Bicarb



CA = Carbonic Anhydrase

Proximal Tubule Bicarb

Clinical Correlations

- Carbonic anhydrase inhibitors
  - Weak diuretics
  - Result in bicarb loss in urine
- Type II Renal Tubular Acidosis
  - Ion defect
  - Inability to absorb bicarb
  - Metabolic acidosis

Fanconi's Syndrome

- Impaired ability of proximal tubule to resorb HCO3-, glucose, amino acids, phosphate, and low molecular weight proteins
- Polyuria, polydipsia (diuresis from glucose)
- Non AG acidosis (loss of HCO_3^-)
- Hypokalemia (↑nephron flow)
- Hypophosphatemia (loss of phosphate resorbtion)
- Growth failure, dehydration in children

Fanconi's Syndrome

- Inherited or acquired syndrome (rare)
- Inherited form associated with cystinosis
  - Lysosomal storage disease
  - Accumulation of cystine
- Acquired causes:
  - Lead poisoning
  - Tenofovir (HIV drug)
  - Tetracycline

Proximal Tubule

Key Points

- Workhorse of the nephron
- Absorbs most water, Na, K, and other molecules
- Loss of amino acids → Hartnup disease
- Glucose in urine → diabetes
- Loss of bicarb in urine
  - Carbonic anhydrase inhibitors
  - Type II RTAs

Proximal Tubule

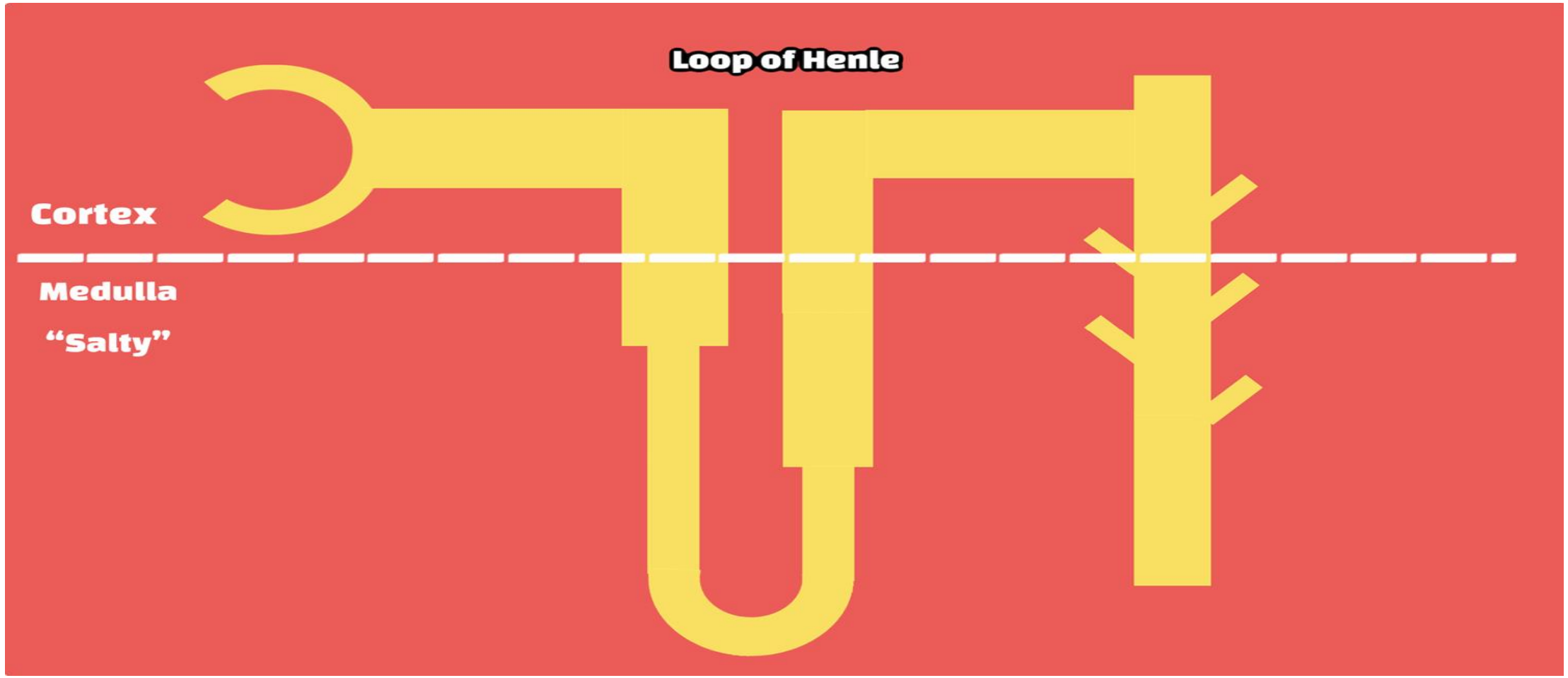
Key Points

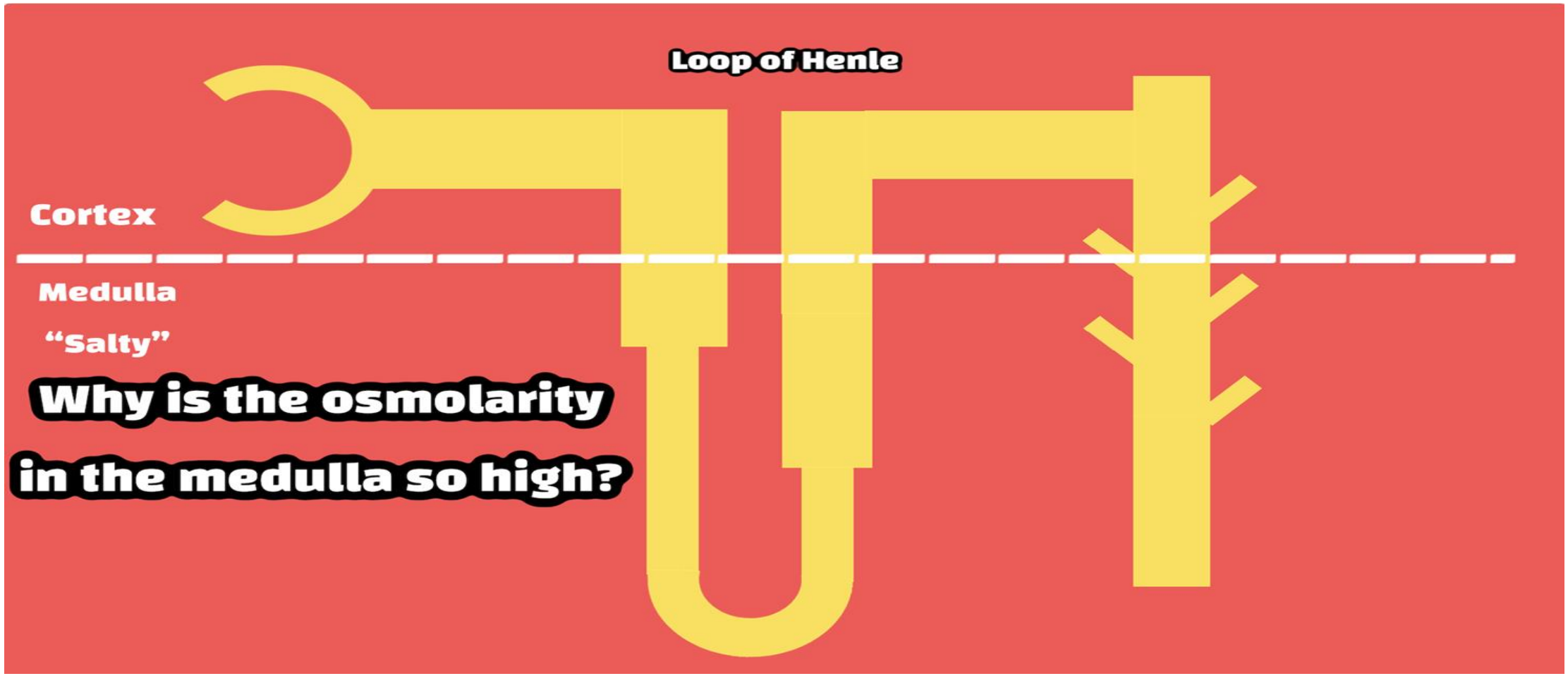
- Most common source renal cell carcinomas
- Most common area damaged acute tubular necrosis

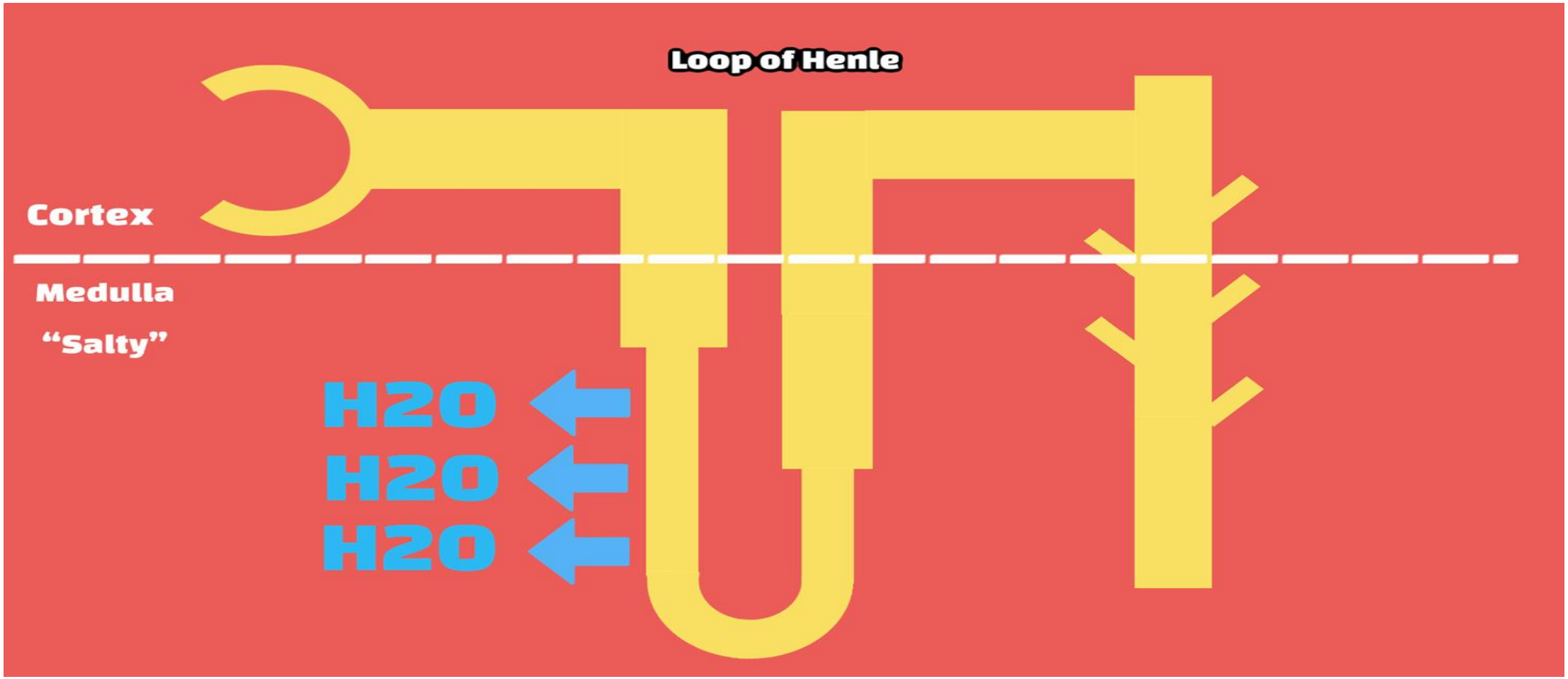
Nephron Physiology

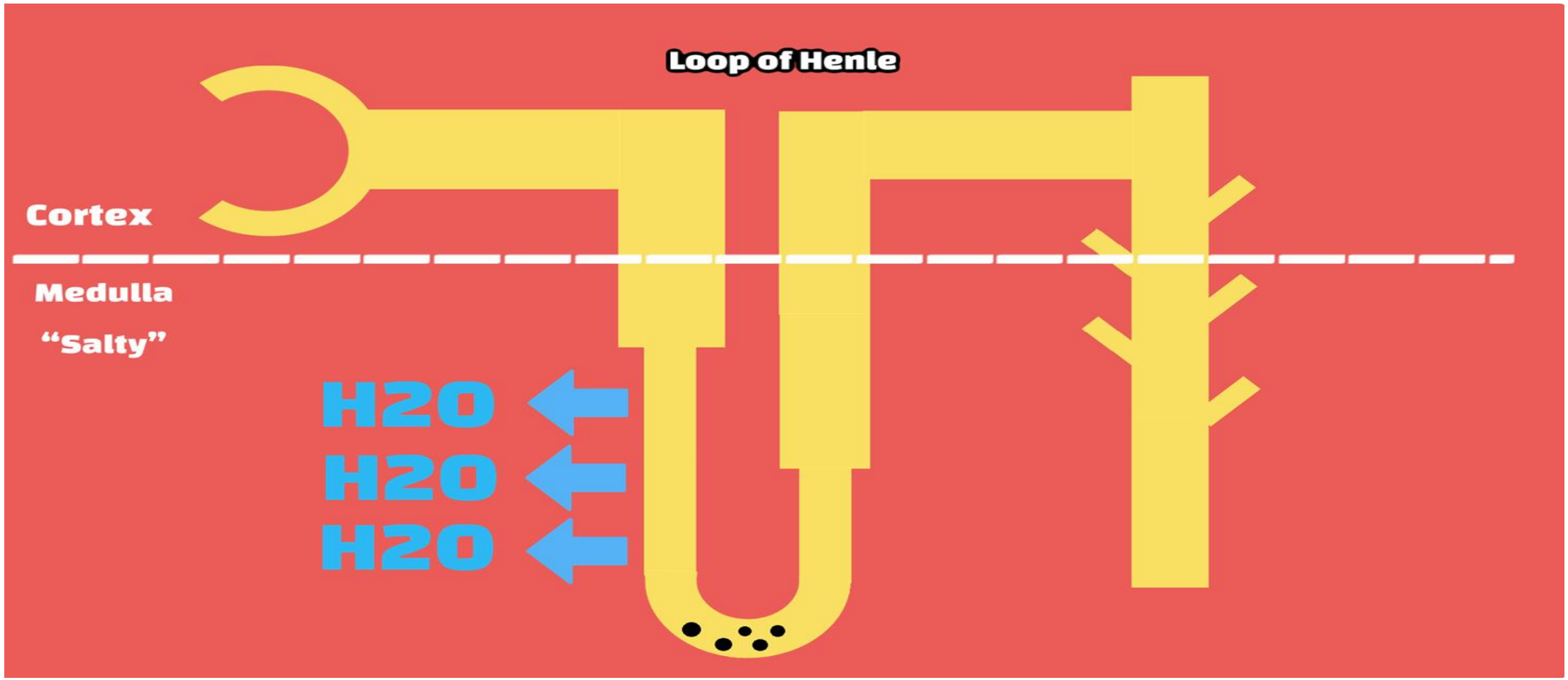
Thin Descending Loop of Henle

- Impermeable to NaCl
- Concentrates urine
- Absorbs water
- Water leaves urine
- Drawn out by hypertonicity in medulla


Loop of Henle
Cortex
Medulla
“Salty”

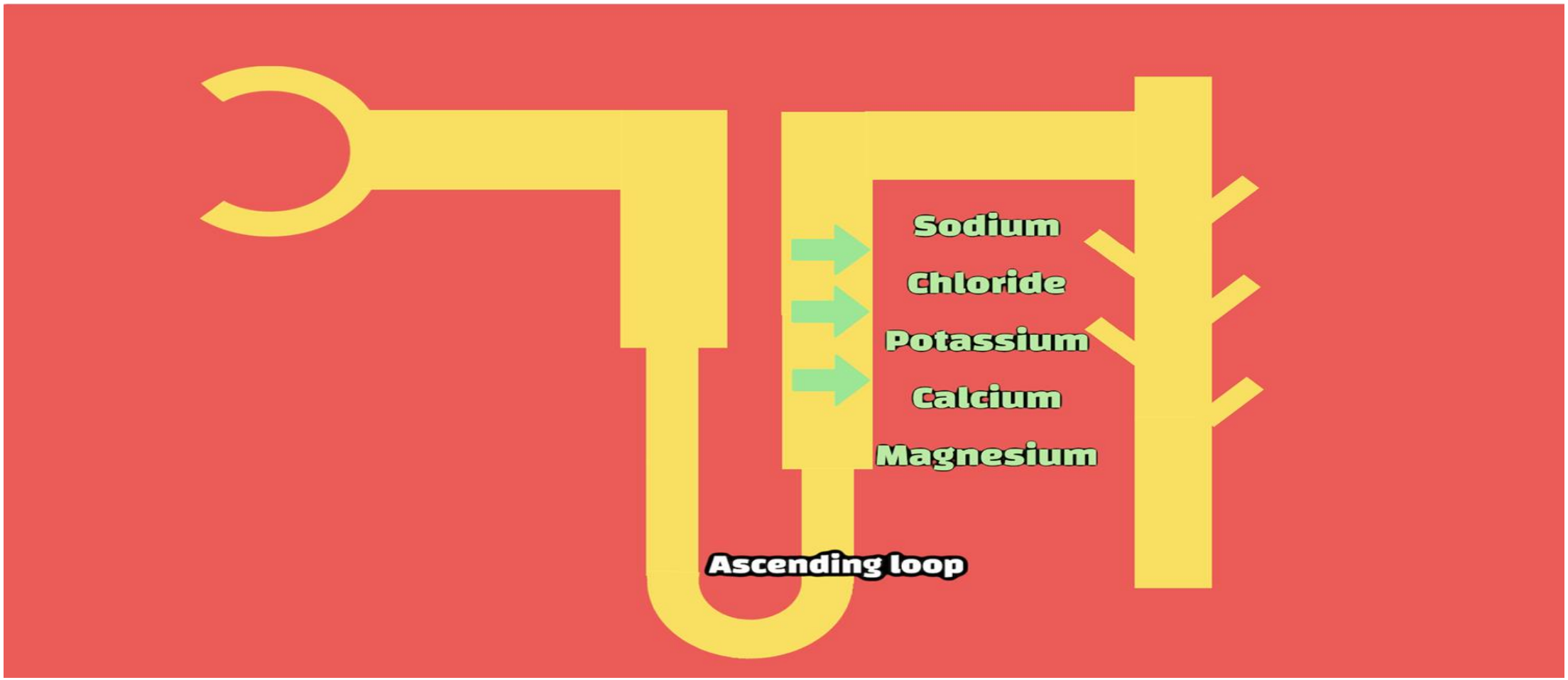

Loop of Henle
Cortex
Medulla
"Salty"
Why is the osmolarity
in the medulla so high?

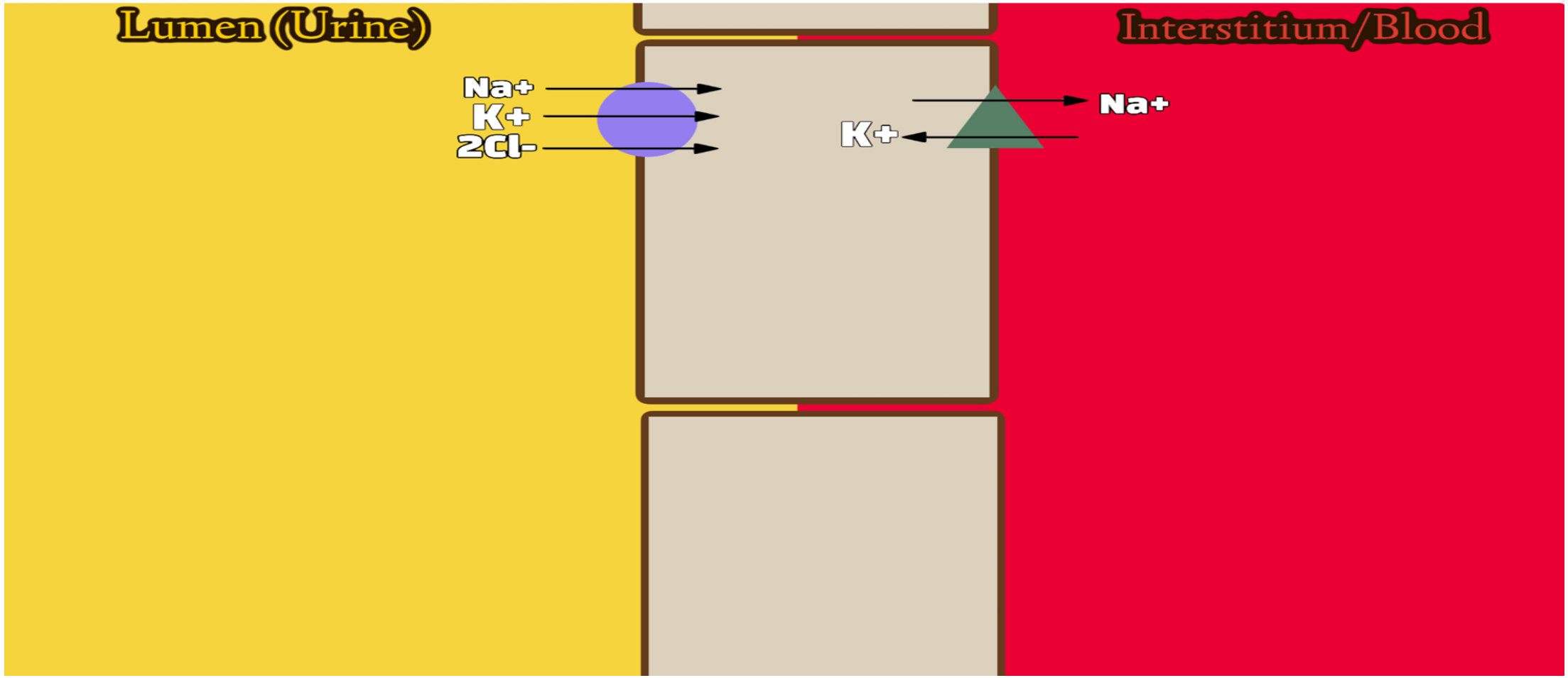

Loop of Henle
Cortex
Medulla
"Salty"
H2O
H2O
H2O

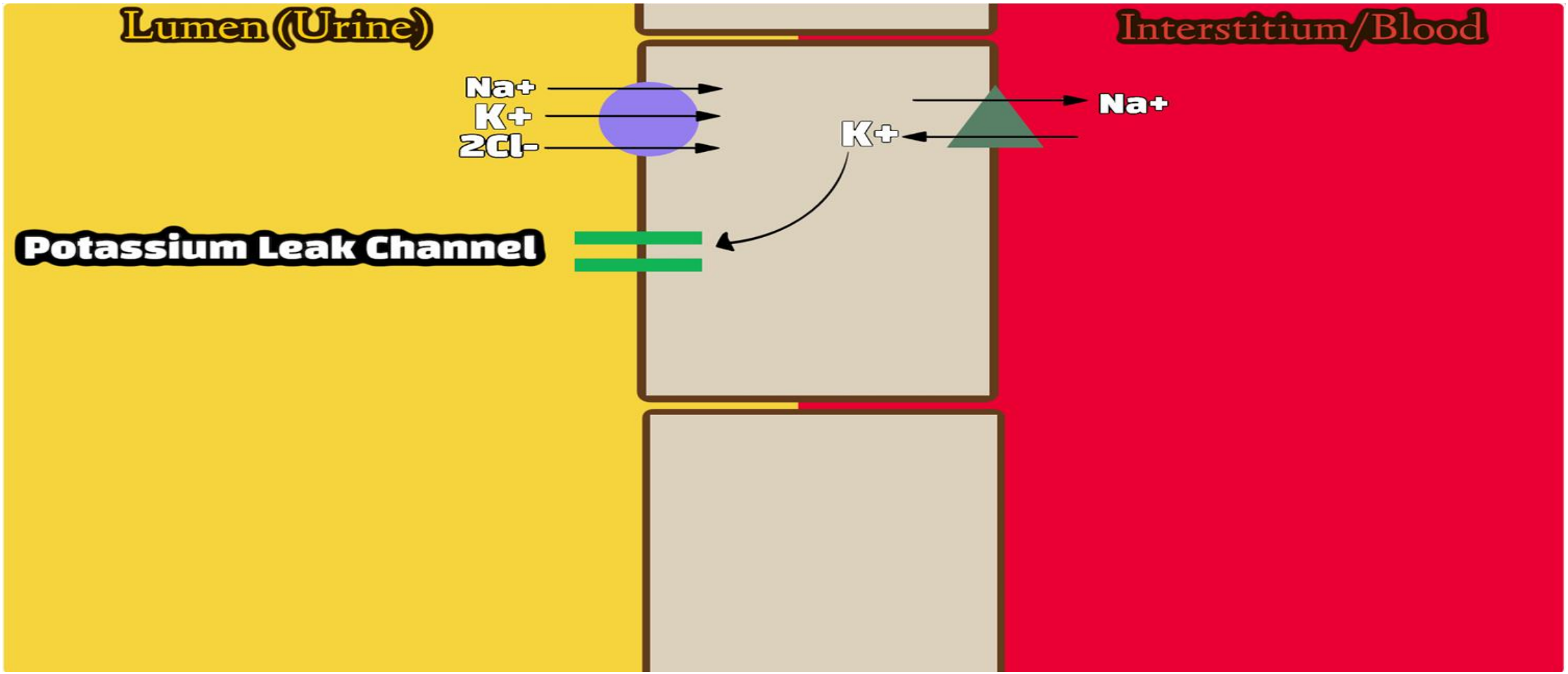

Loop of Henle
Cortex
Medulla
"Salty"
H2O
H2O
H2O

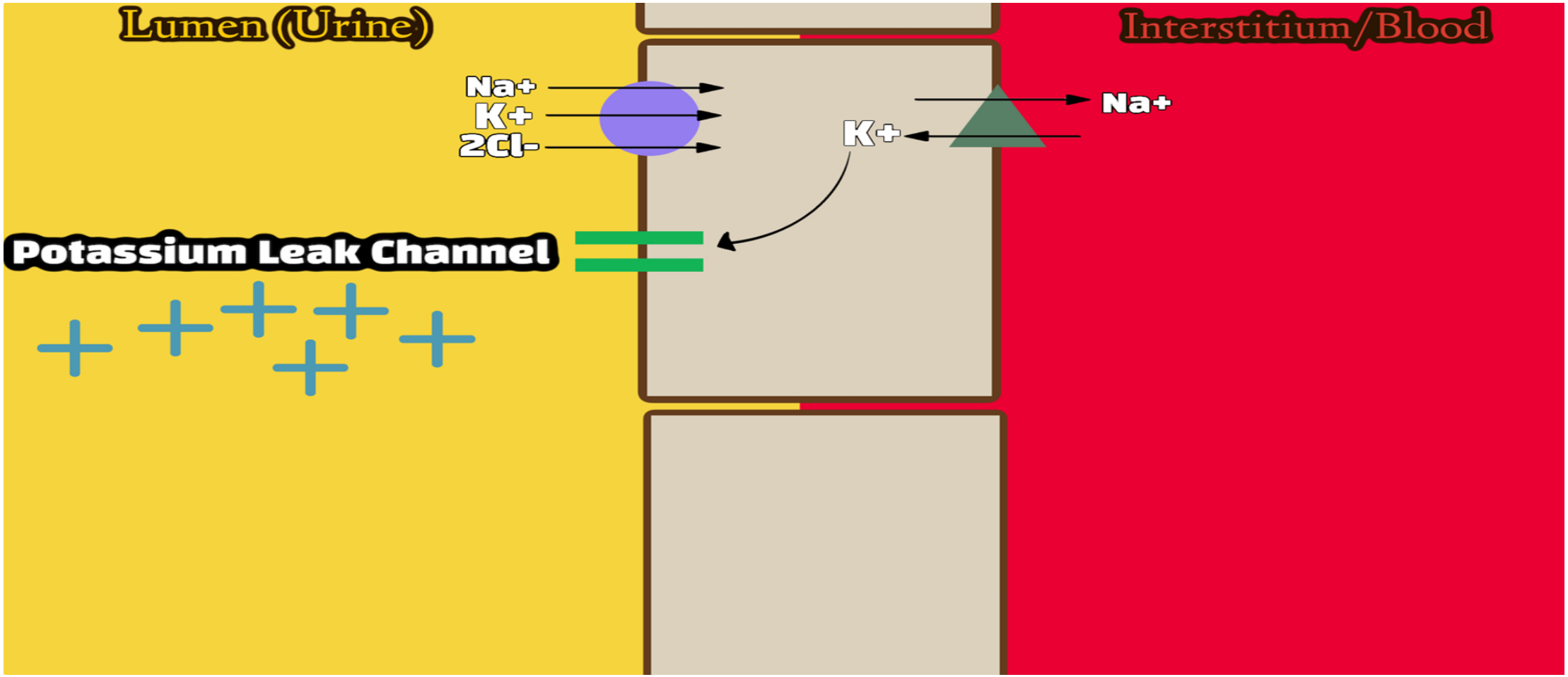
Thick Ascending Loop of Henle

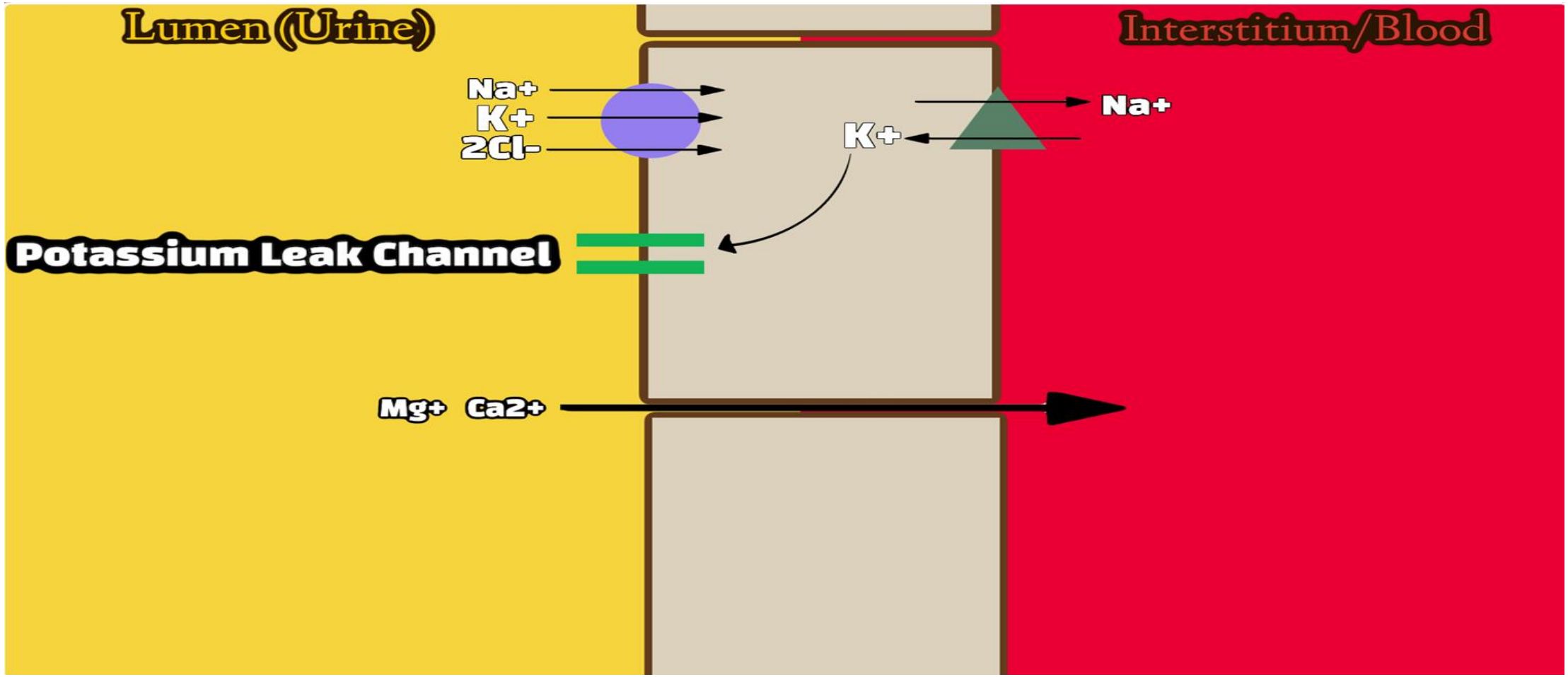
- Impermeable to water
- Reabsorbs Na^+, K^+, Cl^-, Mg^{2+}, and Ca^{2+}
- Makes urine less concentrated as it ascends

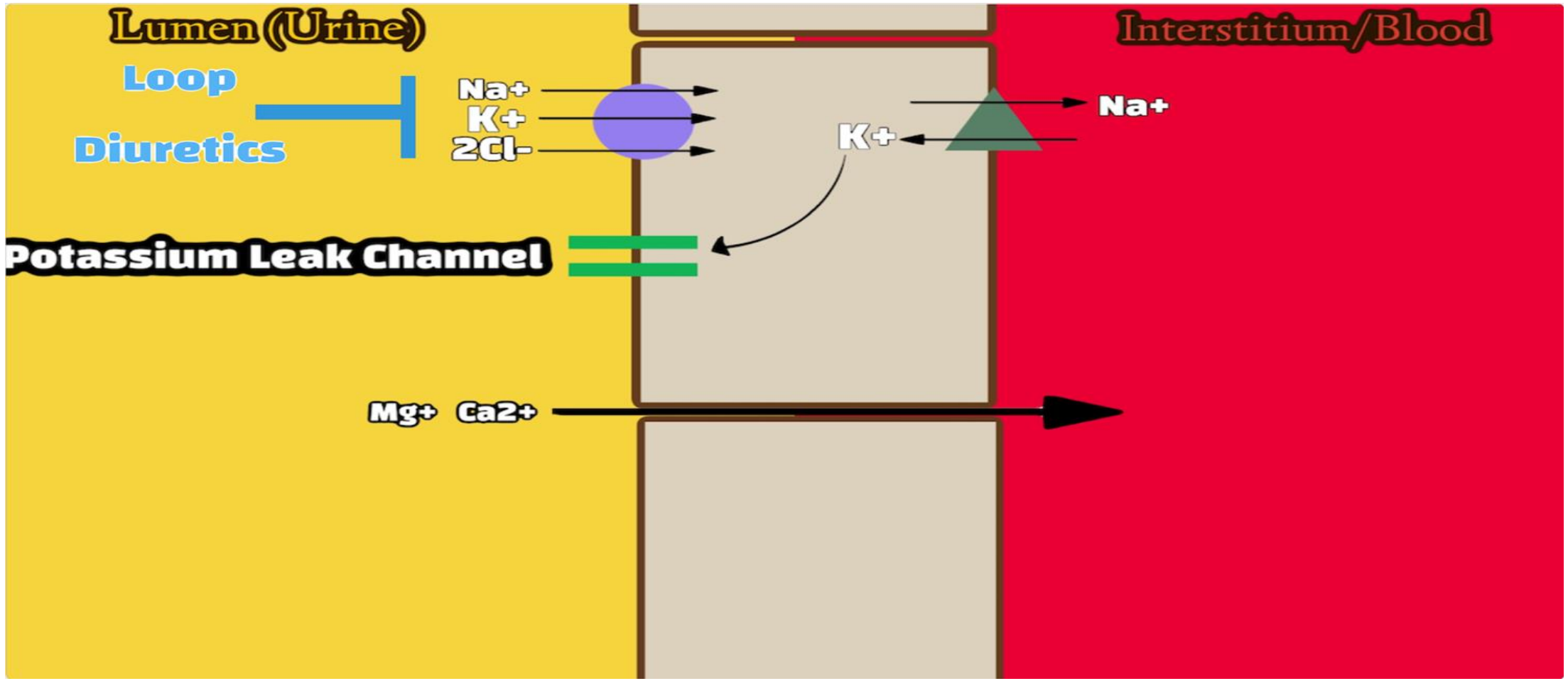

Sodium
Chloride
Potassium
Calcium
Magnesium
Ascending loop


Lumen (Urine)
Interstitium/Blood
Na+
K+
2Cl-
Na+
K+


Lumen (Urine)
Interstitium/Blood
Na+
K+
2Cl-
Na+
K+
Potassium Leak Channel


Lumen (Urine)
Interstitium/Blood
Na+
K+
2Cl-
Na+
K+
Potassium Leak Channel


Lumen (Urine)
Interstitium/Blood
Na+
K+
2Cl-
Na+
K+
Potassium Leak Channel
Mg+
Ca2+

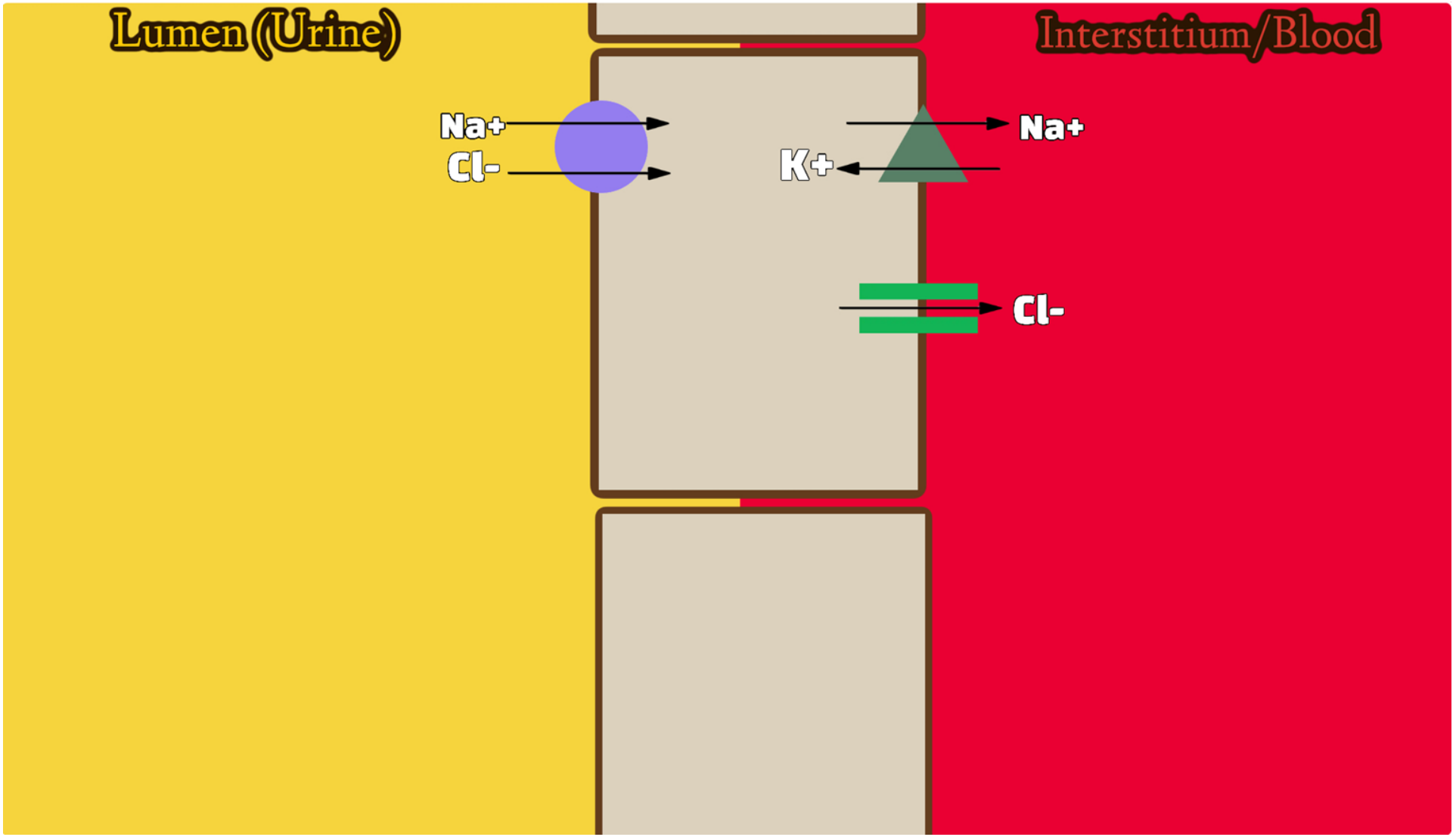

Lumen (Urine)
Interstitium/Blood
Loop
Diuretics
Na+
K+
2Cl-
Na+
K+
Potassium Leak Channel
Mg+
Ca2+

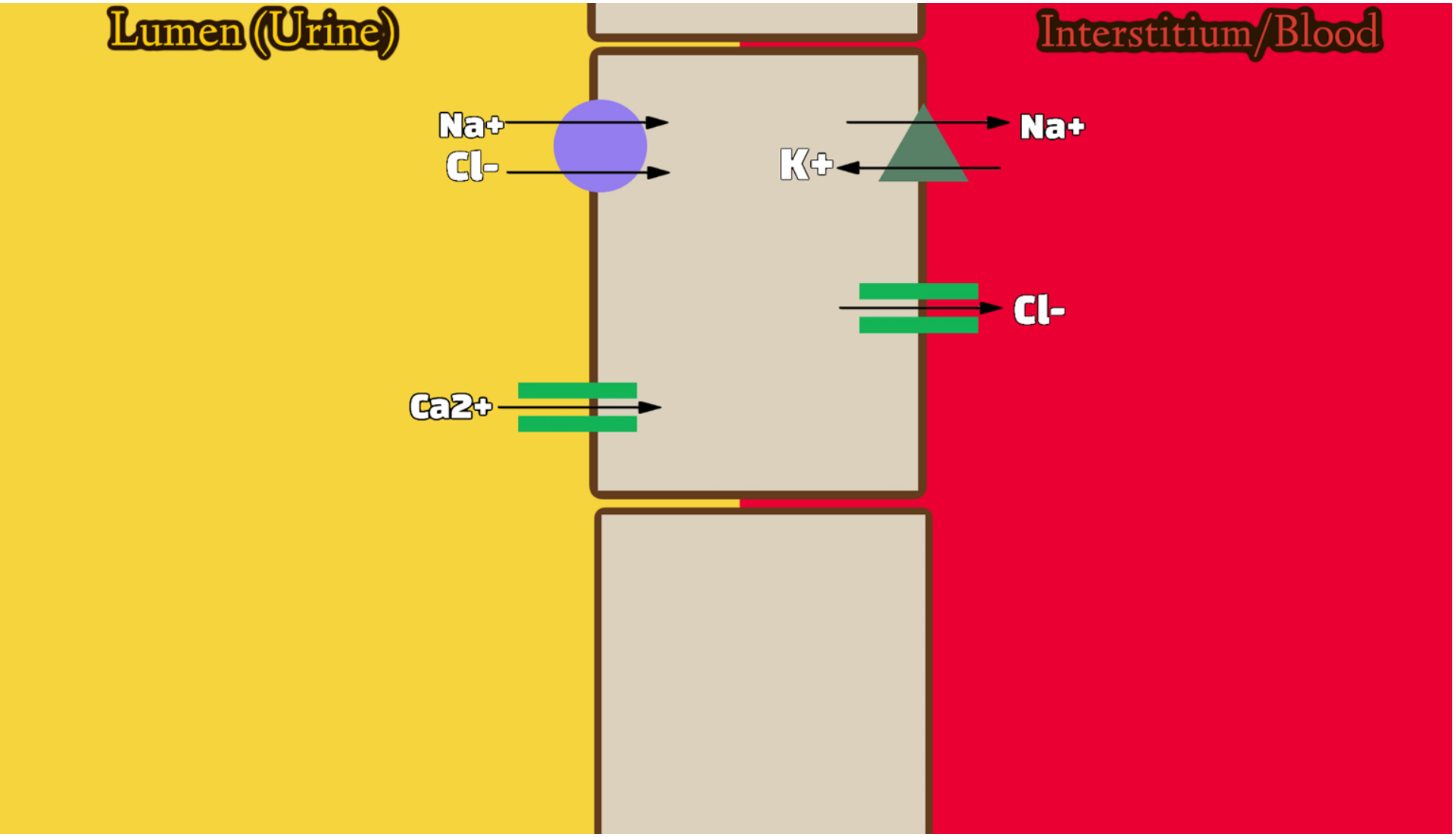
Bartter Syndrome

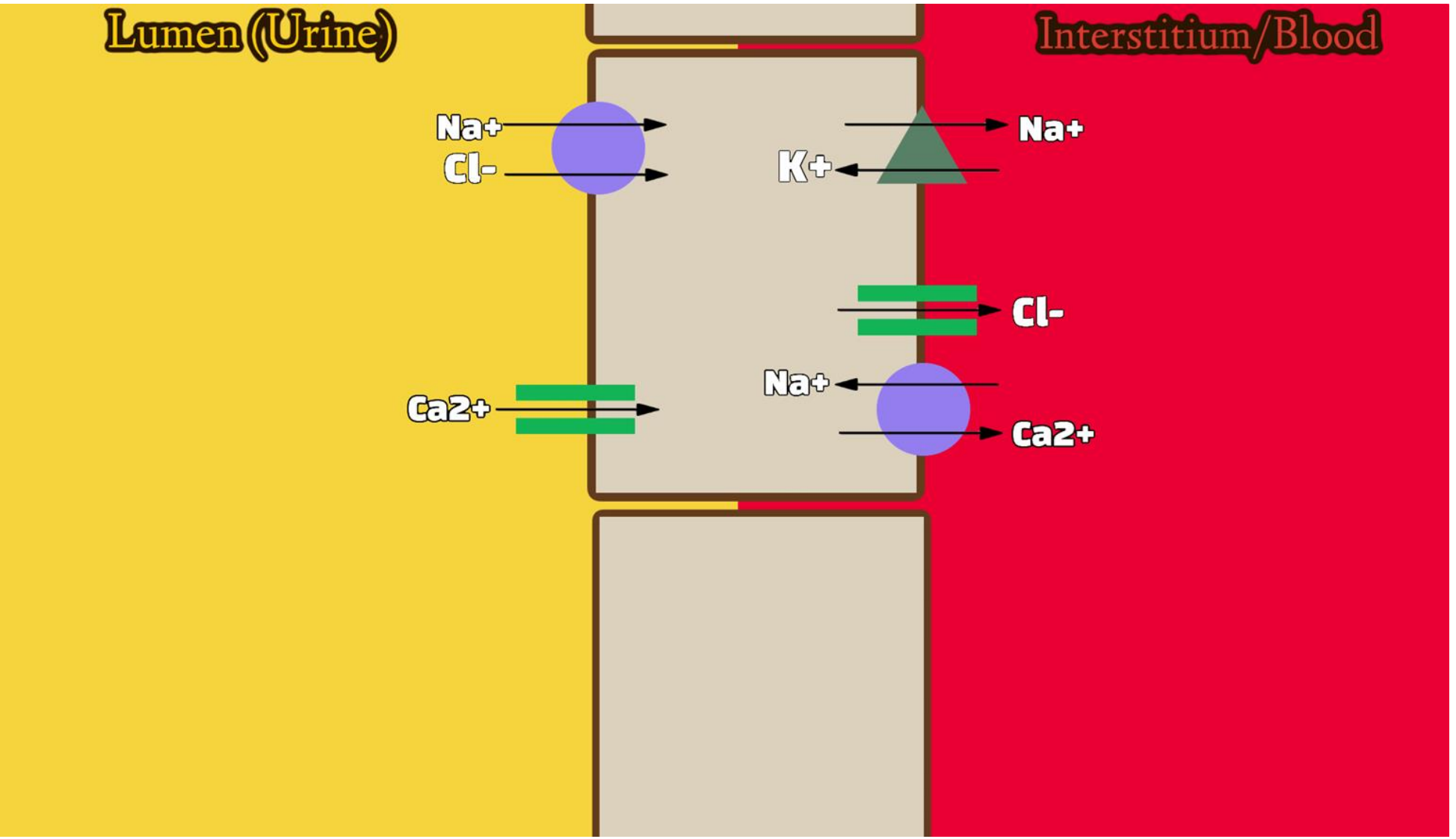
- Resorptive defect in Na/K/2Cl triporter in Thick Ascending Loop of Henle
- Autosomal recessive
- Effects: metabolic alkalosis, hypokalemia, hypercalciuria
- Presents similarly to chronic loop diuretic use

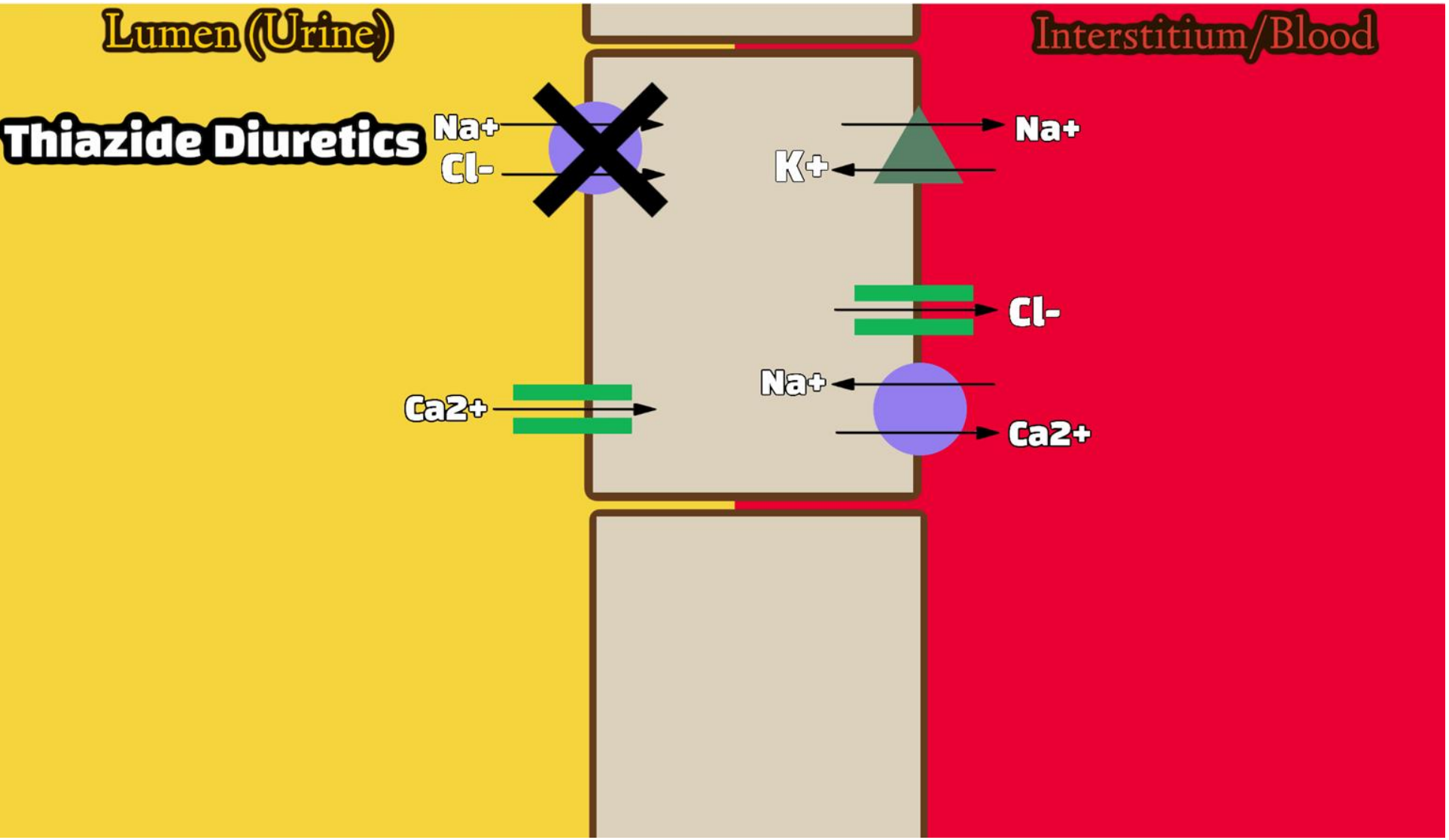
Distal Convoluted Tubule

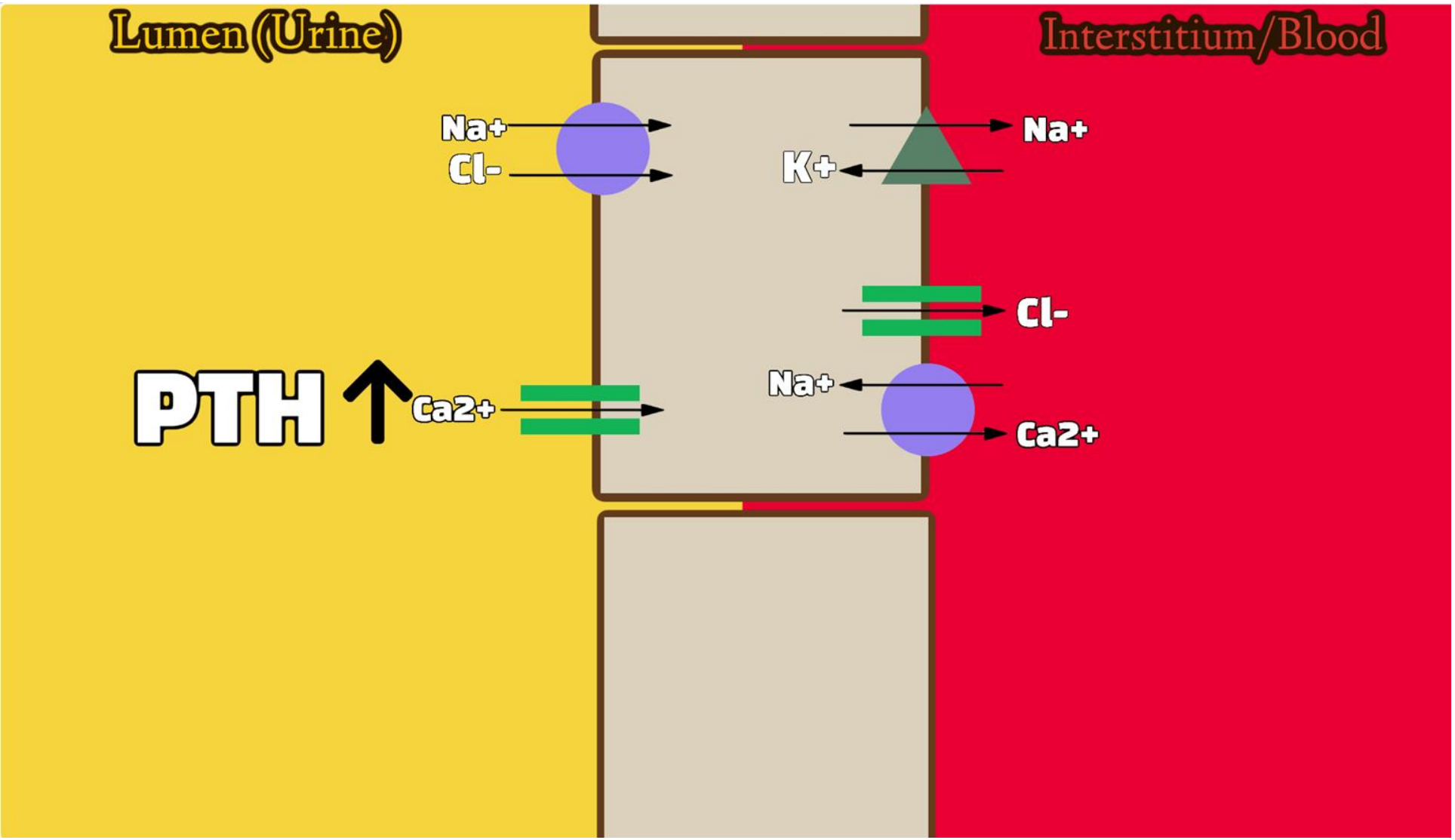
- Impermeable to water
- Reabsorbs Na+, Cl-
- Makes urine fully dilute (hypotonic)
- PTH leads to calcium reabsorption


Lumen (Urine)
Interstitium/Blood
Na+
Cl-
K+
Na+
Cl-


Lumen (Urine)
Interstitium/Blood
Na+
Cl-
K+
Na+
Cl-
Ca2+

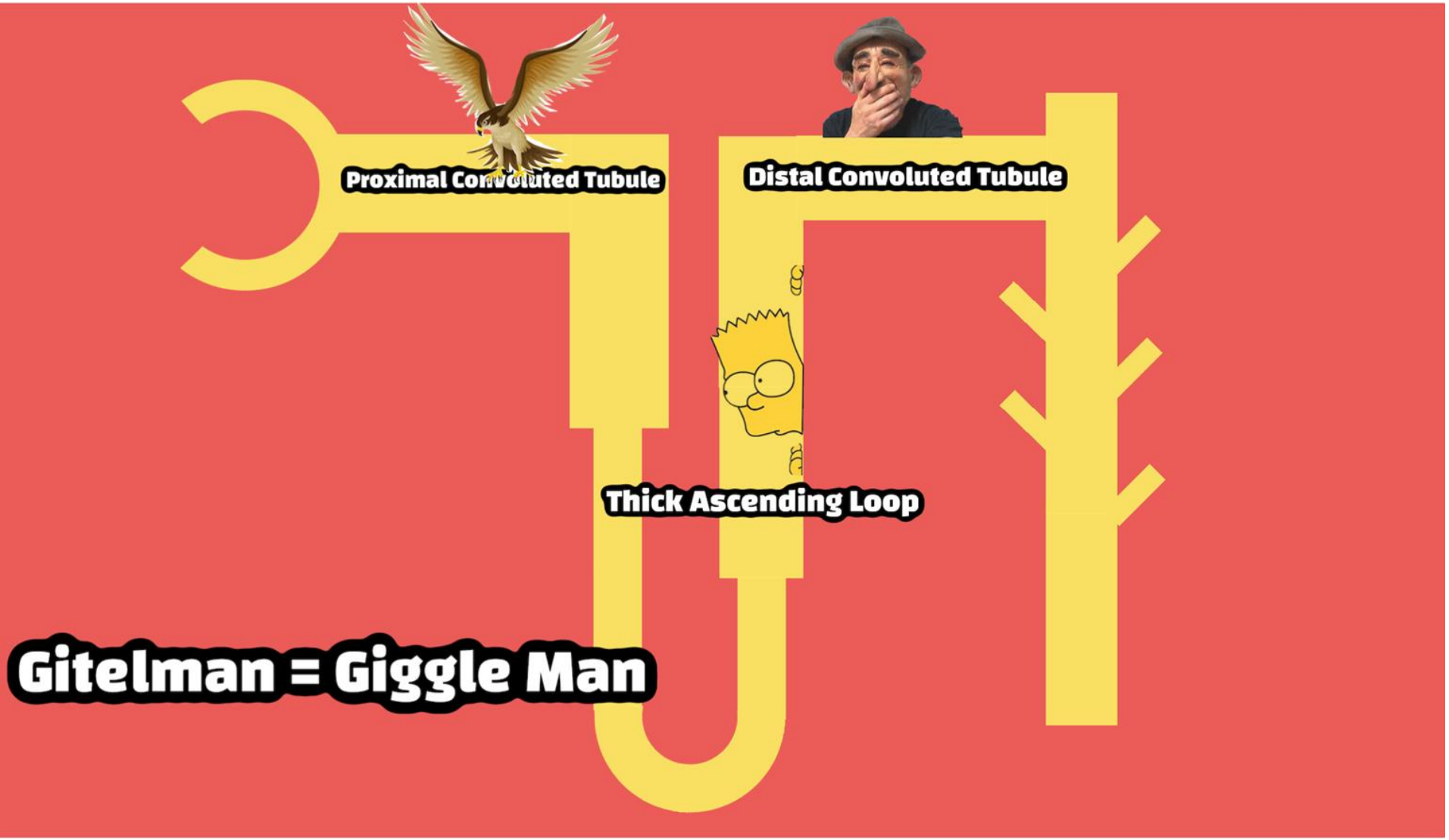

Lumen (Urine)
Interstitium/Blood
Na+
Cl-
K+
Na+
Cl-
Na+
Ca2+
Ca2+


Lumen (Urine)
Interstitium/Blood
Thiazide Diuretics
Na+
Cl-
K+
Na+
Cl-
Na+
Ca2+
Ca2+


Lumen (Urine)
Interstitium/Blood
Na+
Cl-
K+
Na+
Cl-
PTH
Ca2+
Na+
Ca2+

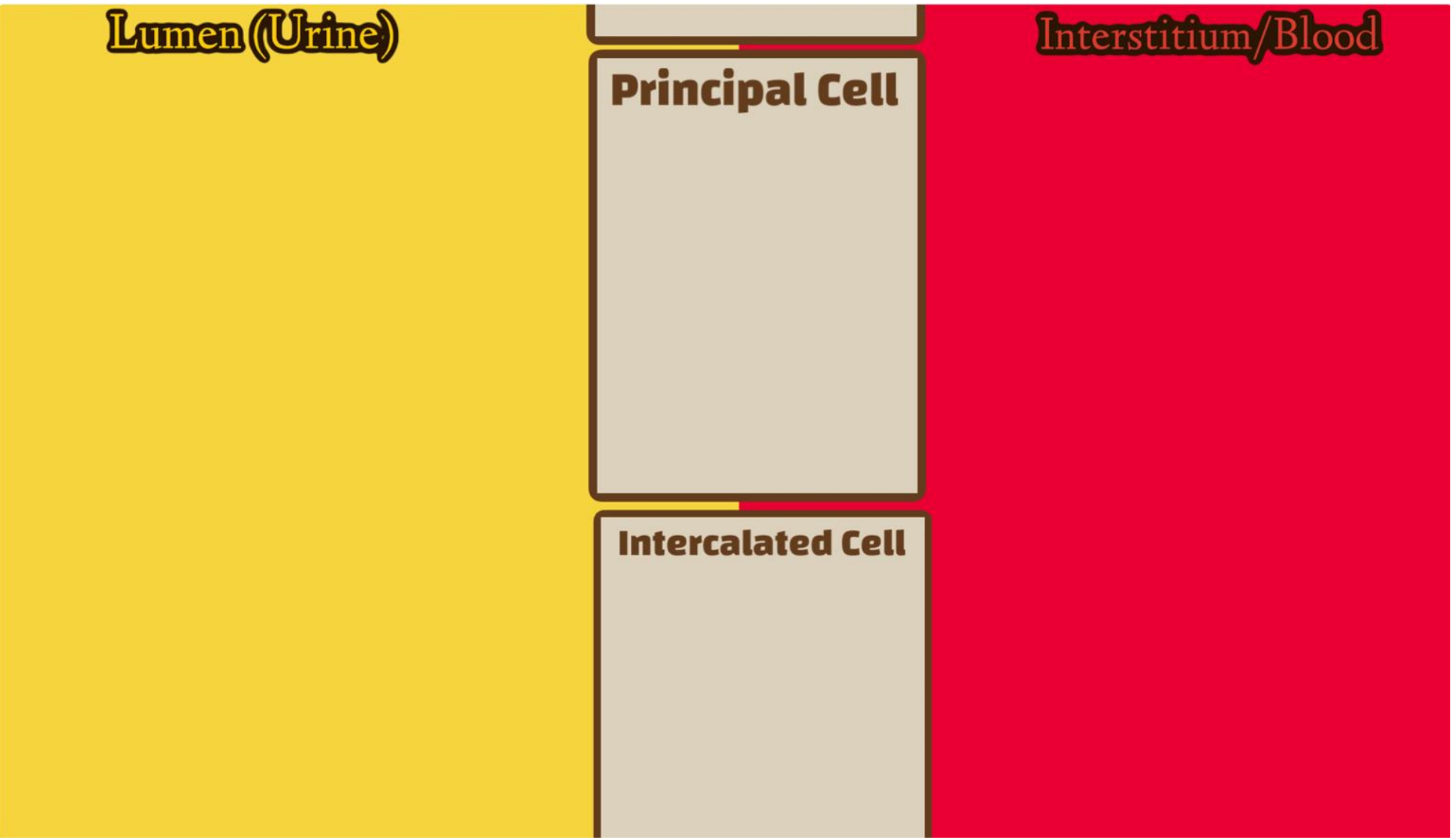
Gitelman Syndrome

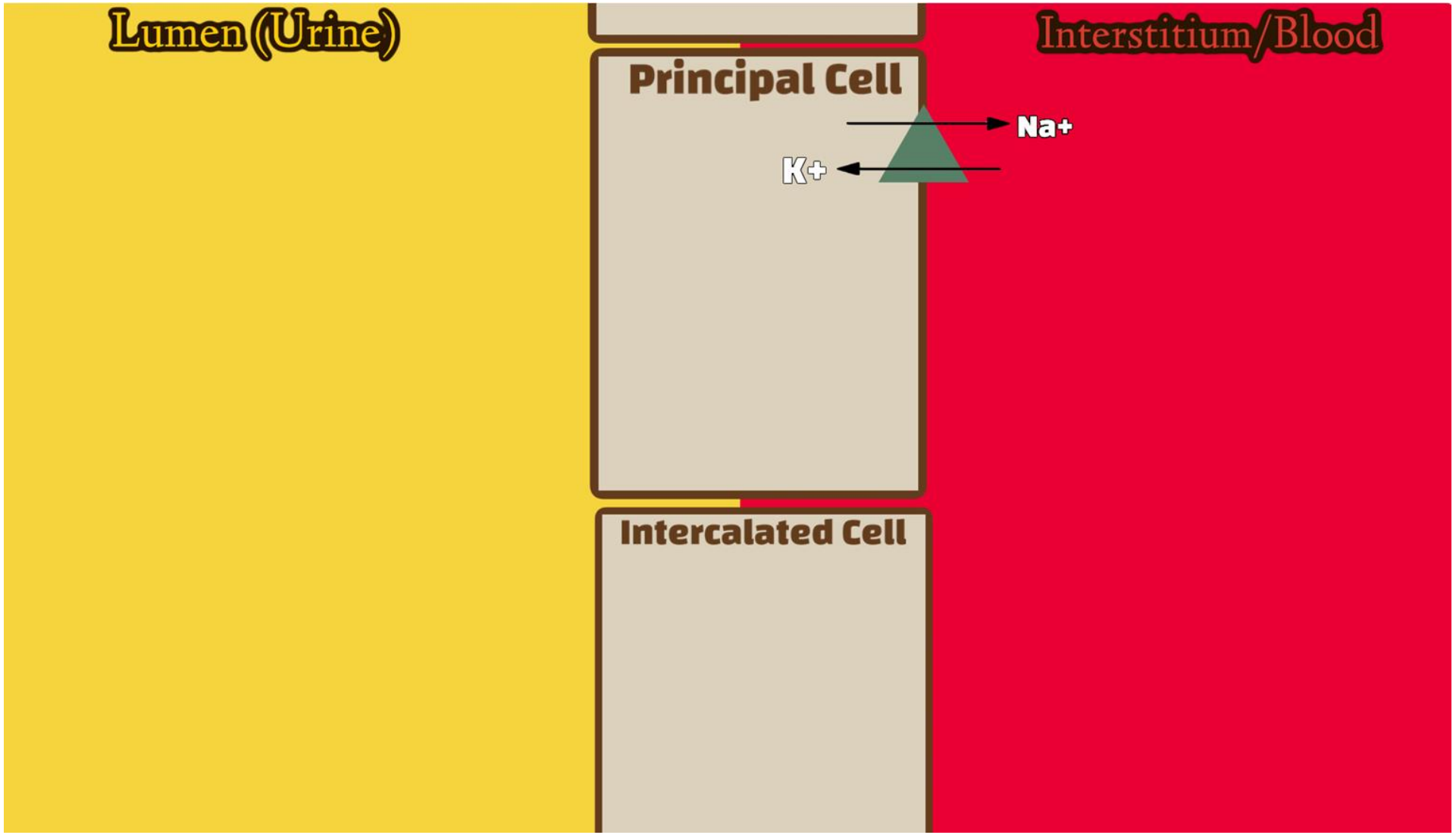
- Resorption defect of NaCl in DCT
- Autosomal recessive
- Effects: Metabolic Alkalosis, hypomagnesemia, hypokalemia, hypocalciuria
- Presents similarly to lifelong thiazide diuretic use

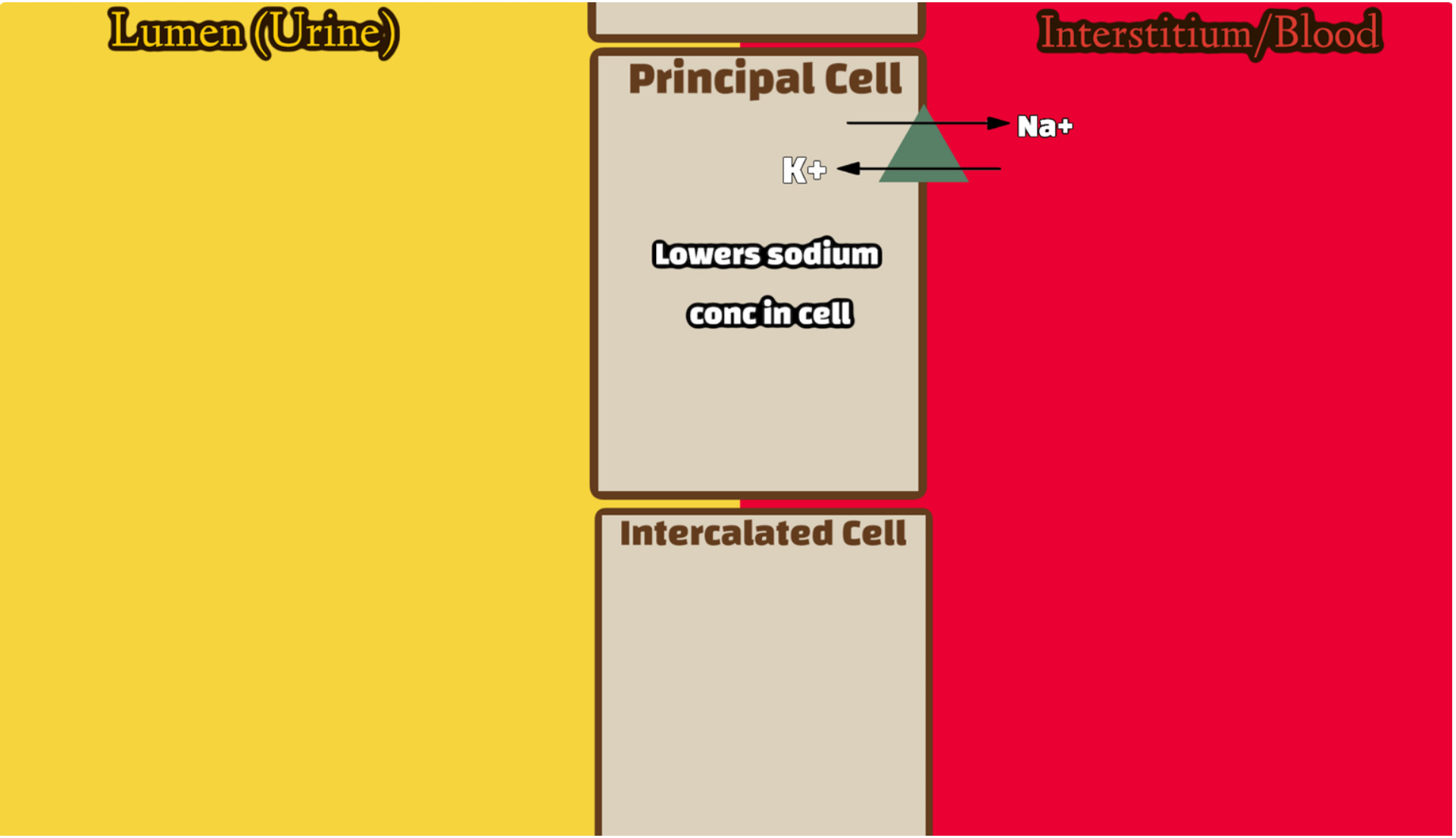

Proximal Convoluted Tubule
Distal Convoluted Tubule
Thick Ascending Loop
Gitelman = Giggle Man

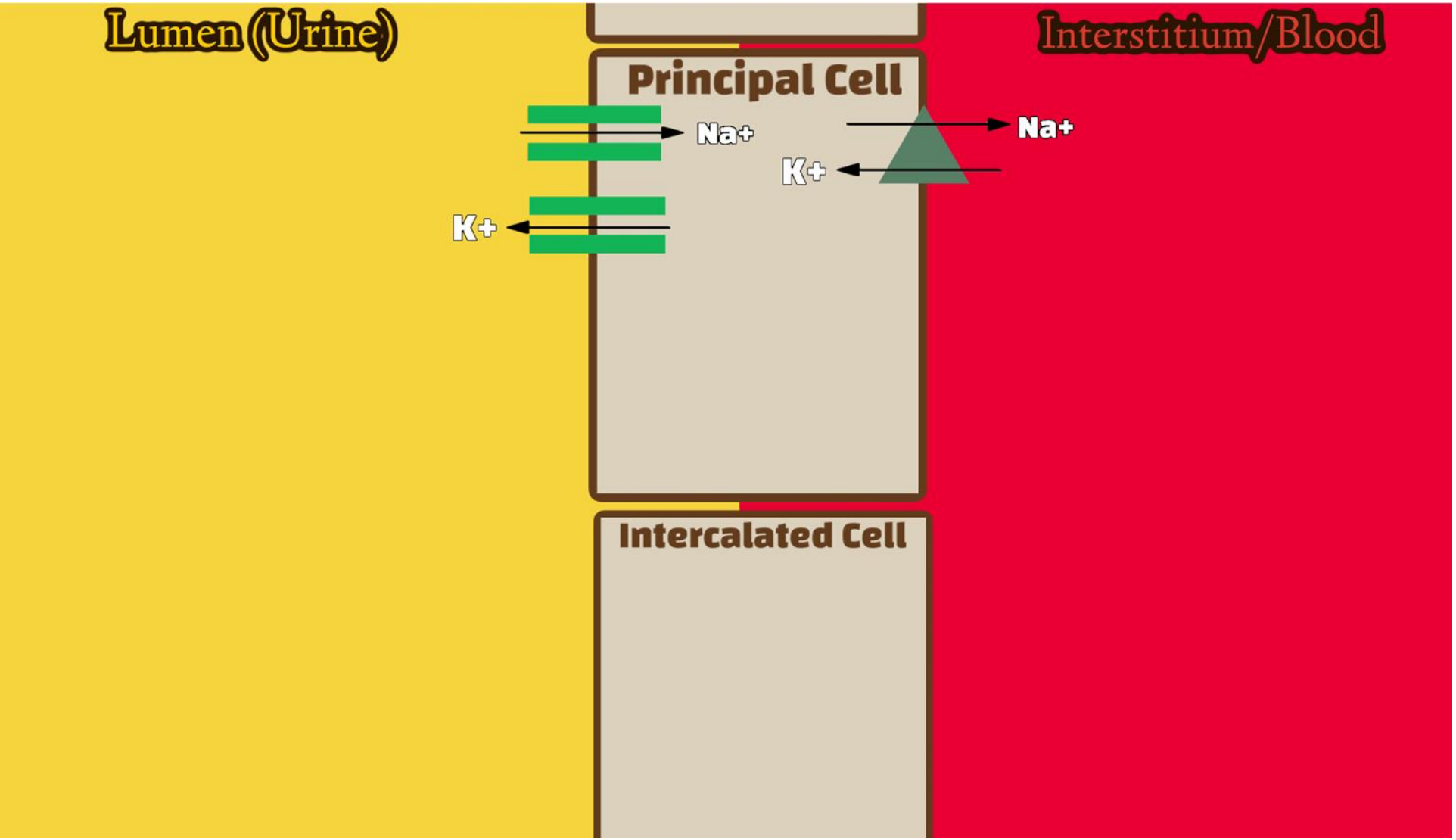
Collecting Tubule

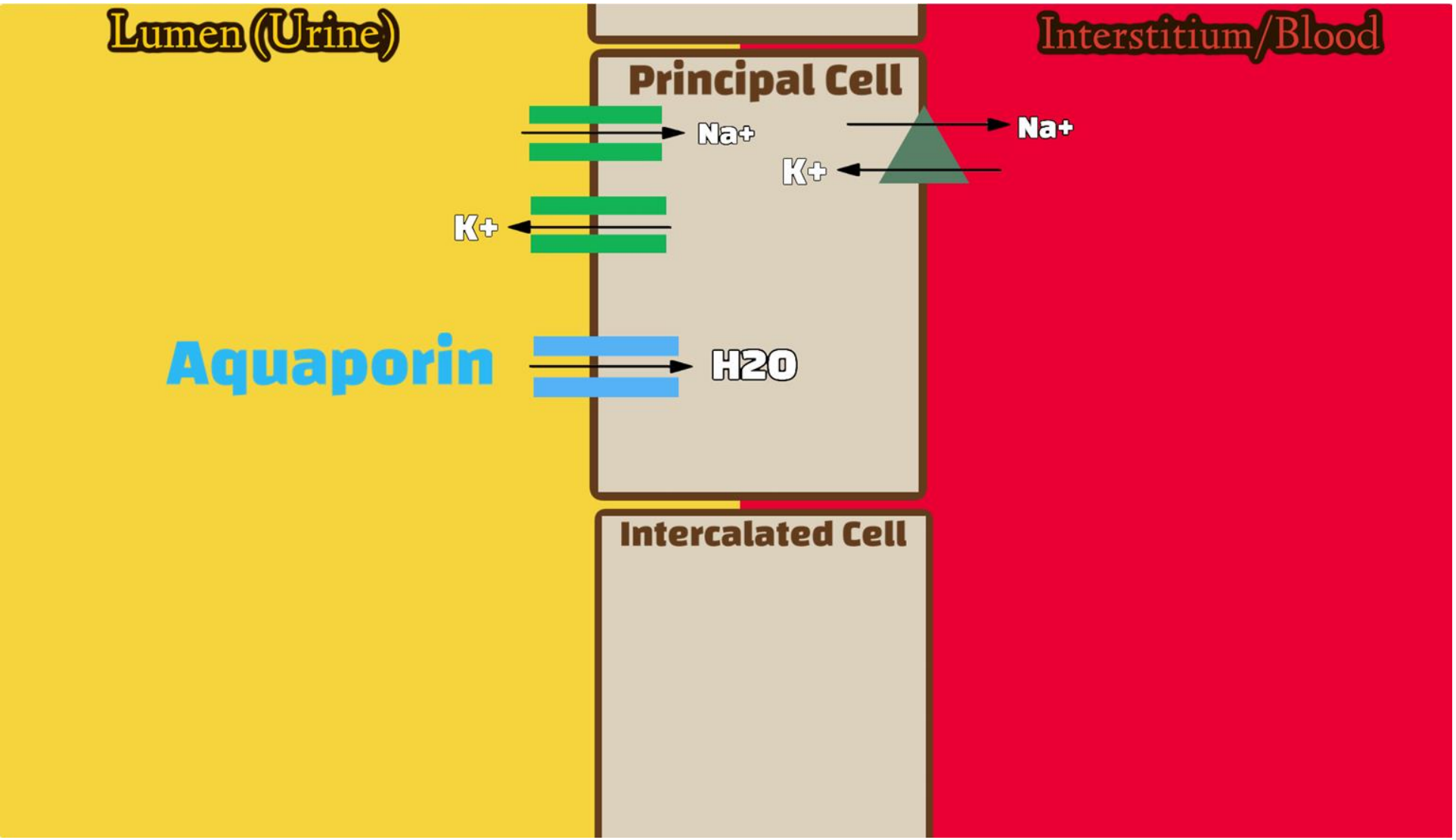
- Reabsorbs Na+ in exchange for secreting K+ and H+(regulated by aldosterone)
- ADH acts at V2 receptors (insertion of aquaporin H20 channels on apical side)
- Increased Na delivery to Collecting Tubule will lead to increased K excretion (cont hypo kale is with loops/thiazides)

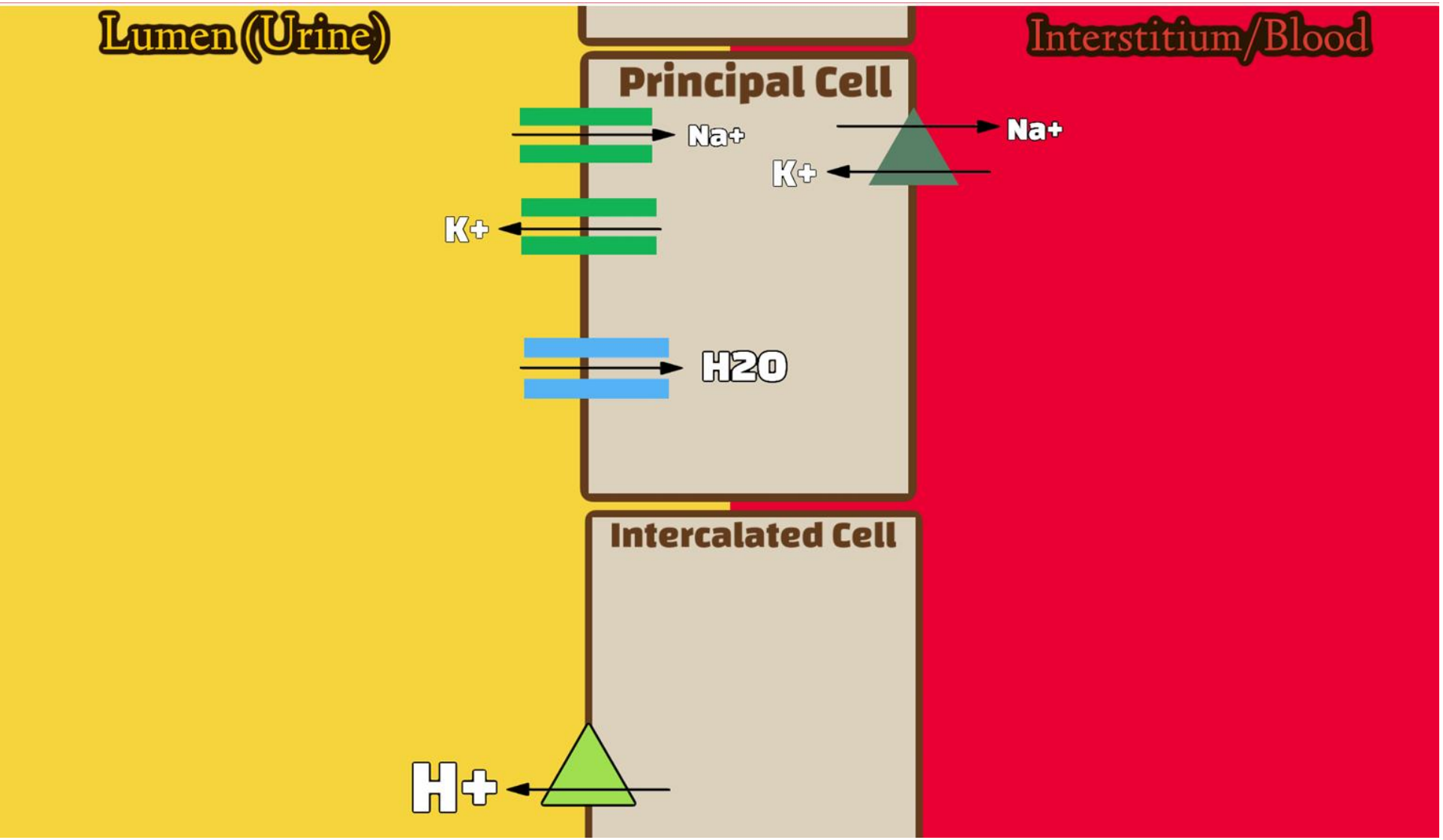

Lumen (Urine)
Interstitium/Blood
Principal Cell
Intercalated Cell

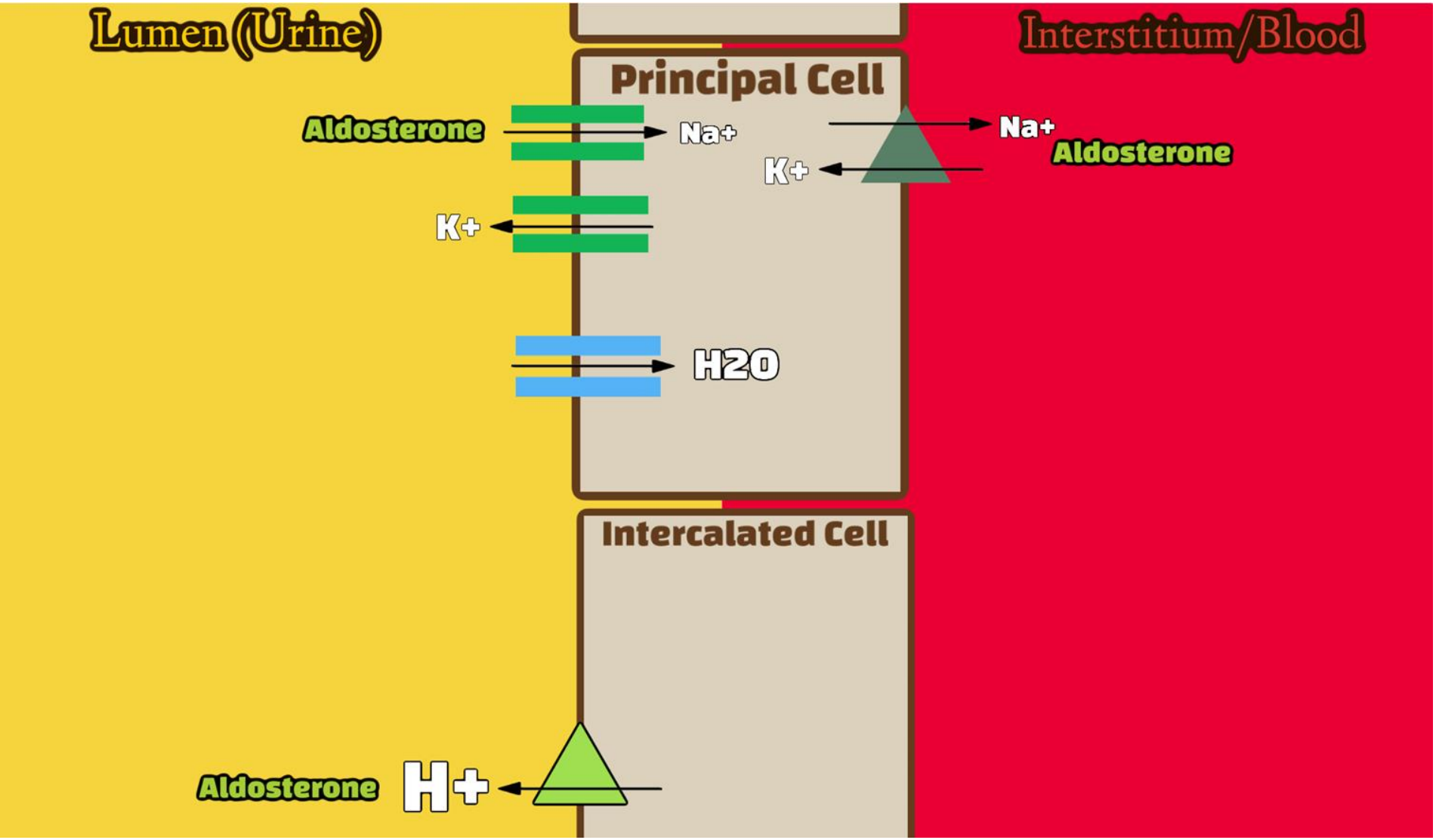

Lumen (Urine)
Interstitium/Blood
Principal Cell
Na+
K+
Intercalated Cell


Lumen (Urine)
Interstitium/Blood
Principal Cell
Na+
K+
Lowers sodium conc in cell
Intercalated Cell


Lumen (Urine)
Interstitium/Blood
Principal Cell
Na+
Na+
K+
K+
Intercalated Cell

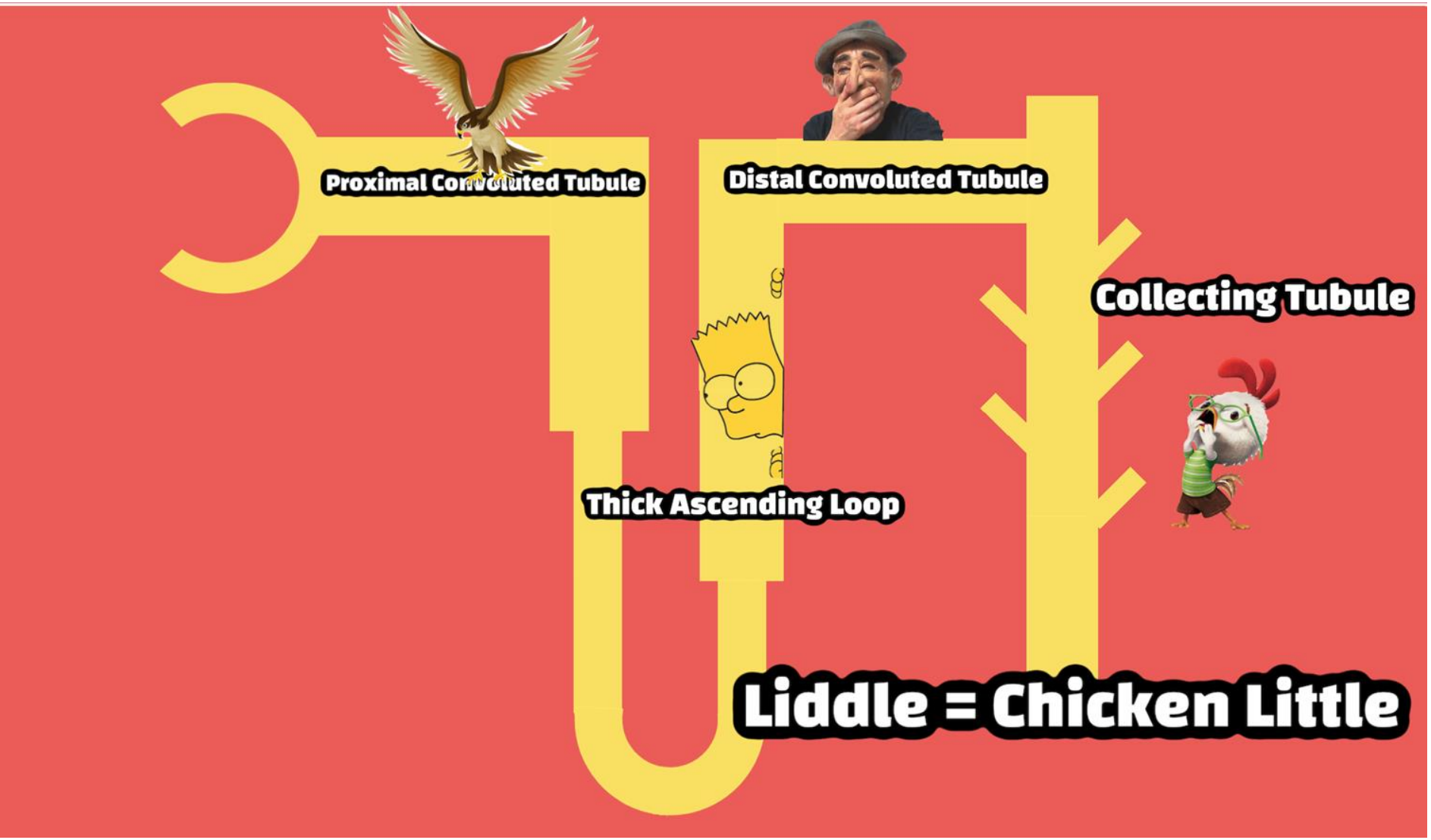

Lumen (Urine)
Interstitium/Blood
Principal Cell
Na+
Na+
K+
K+
Aquaporin
H2O
Intercalated Cell

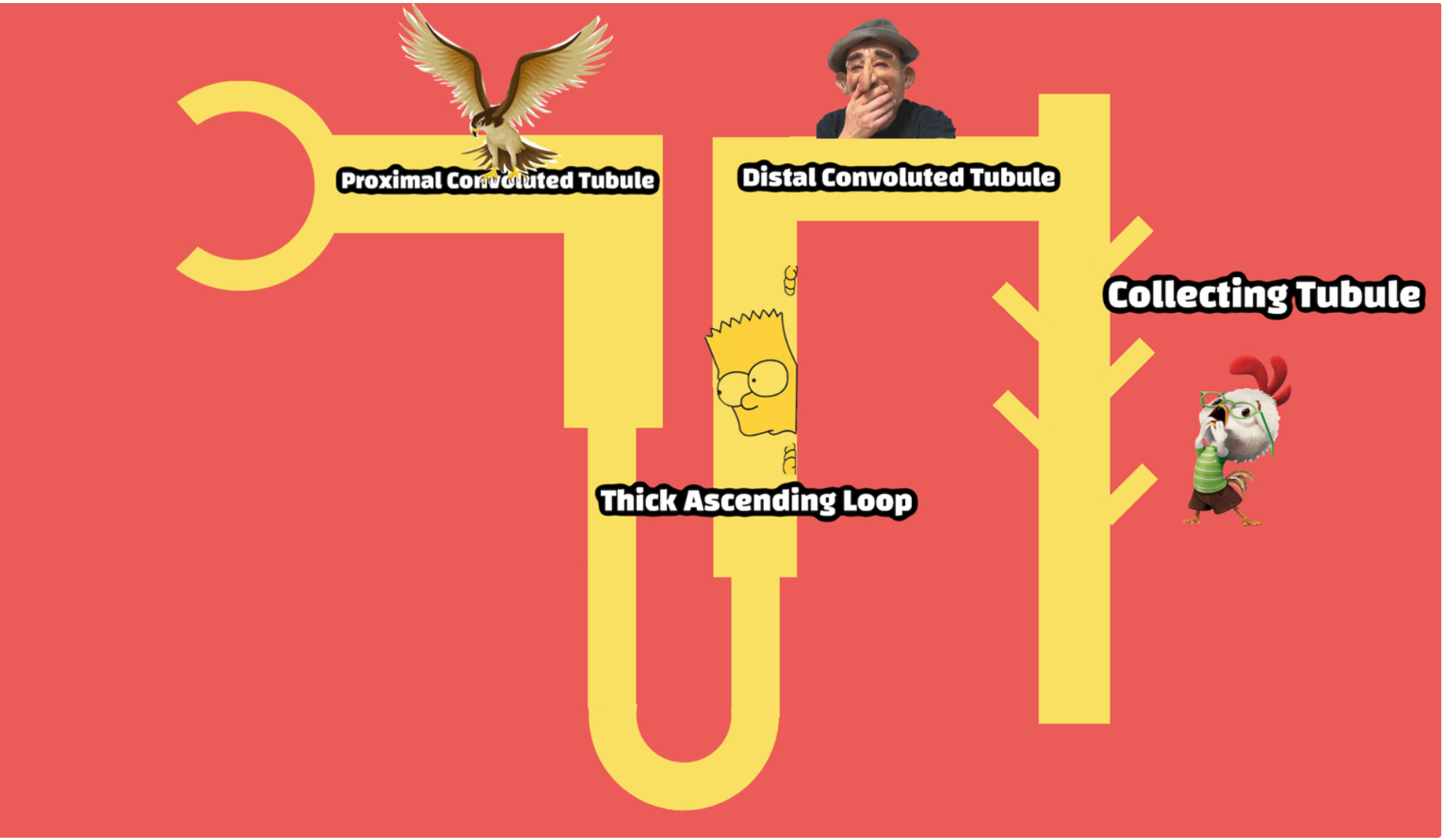

Lumen (Urine)
Interstitium/Blood
Principal Cell
Na+
Na+
K+
K+
H2O
Intercalated Cell
H+


Lumen (Urine)
Interstitium/Blood
Principal Cell
Aldosterone
Na+
Na+
Aldosterone
K+
K+
H2O
Intercalated Cell
Aldosterone
H+

Liddle Syndrome

- Gain of function mutation. Increased activity of Na+ channels leads to increased Na+ Reabsorption in collecting tubules
- Autosomal dominant
- Effects: metabolic alkalosis, hypokalemia, hypertension, decreases aldosterone
- Presents similarly to hyperaldosteronism


Proximal Convoluted Tubule
Distal Convoluted Tubule
Collecting Tubule
Thick Ascending Loop
Liddle = Chicken Little


Proximal Convoluted Tubule
Distal Convoluted Tubule
Collecting Tubule
Thick Ascending Loop

RENAL ENDOCRINOLOGY

RENAL HORMONES

RELEASED by kidney:

1)Erythropoietin

2)Renin

3)Vitamin D

ACT on kidney:

1)Angiotensin II

2)ANP (Atrial natriuretic factors/peptides)

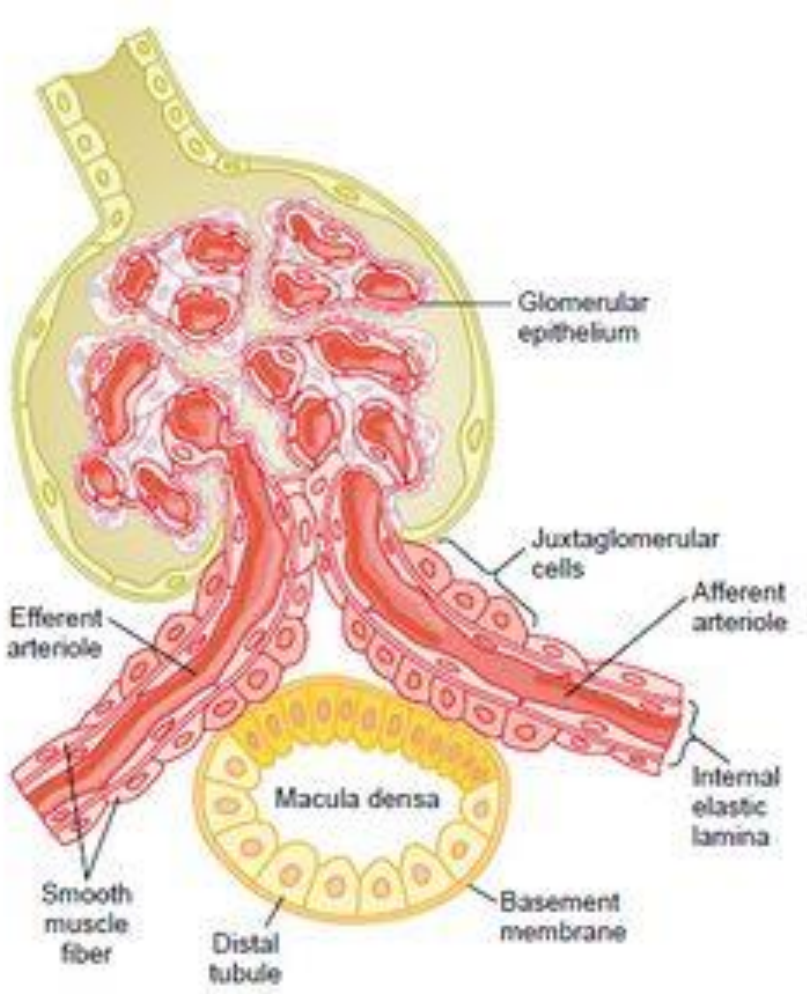
3) ADH (antidiuretic hormone)

4) Aldosterone

5)PTH (parathyroid hormone)

RENIN

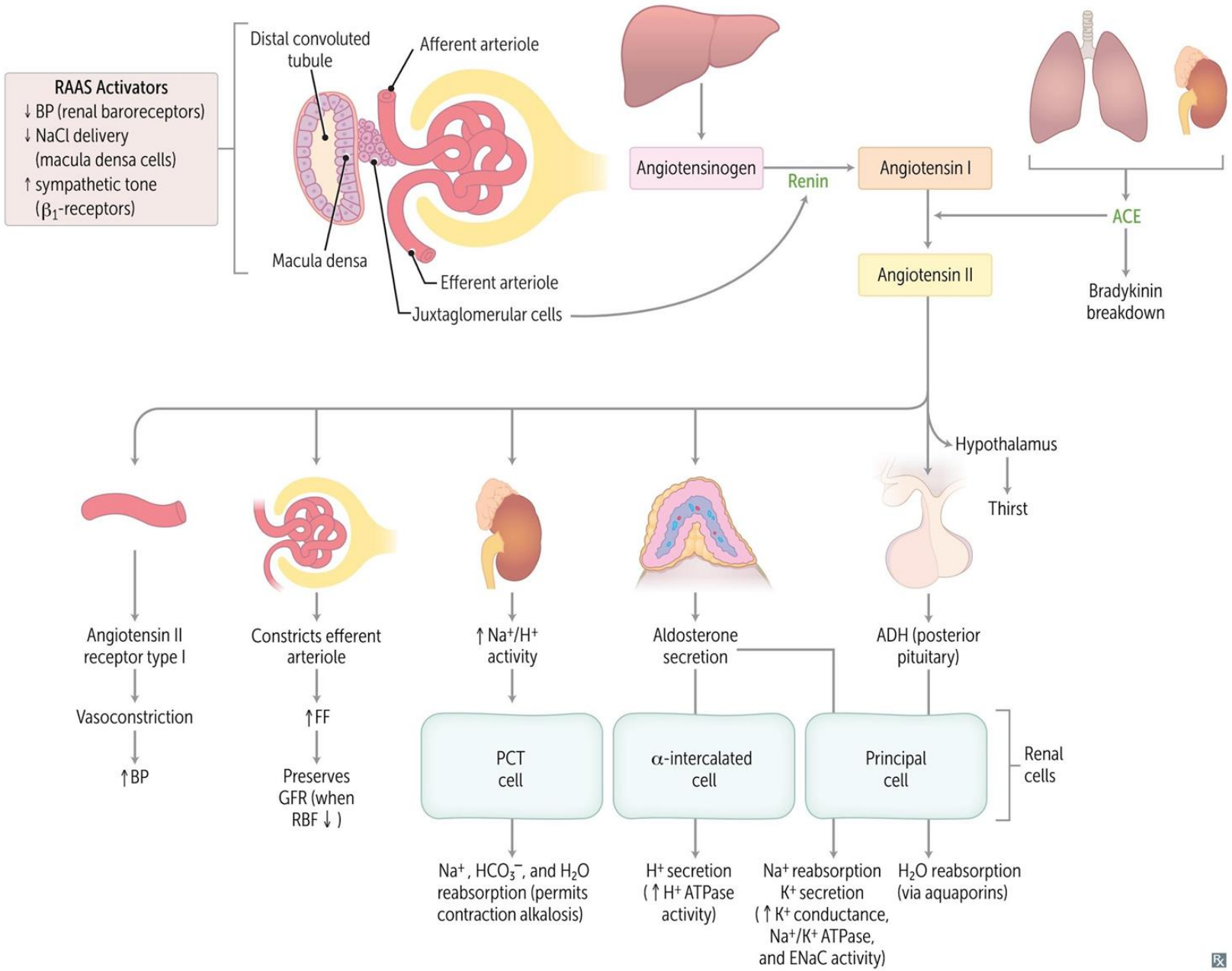
- Secreted by juxtaglomerular cells
- Triggered by macula densa



Stimuli For Renin Release

- Low perfusion pressure
- Low NaCl delivery
- Sympathetic activation

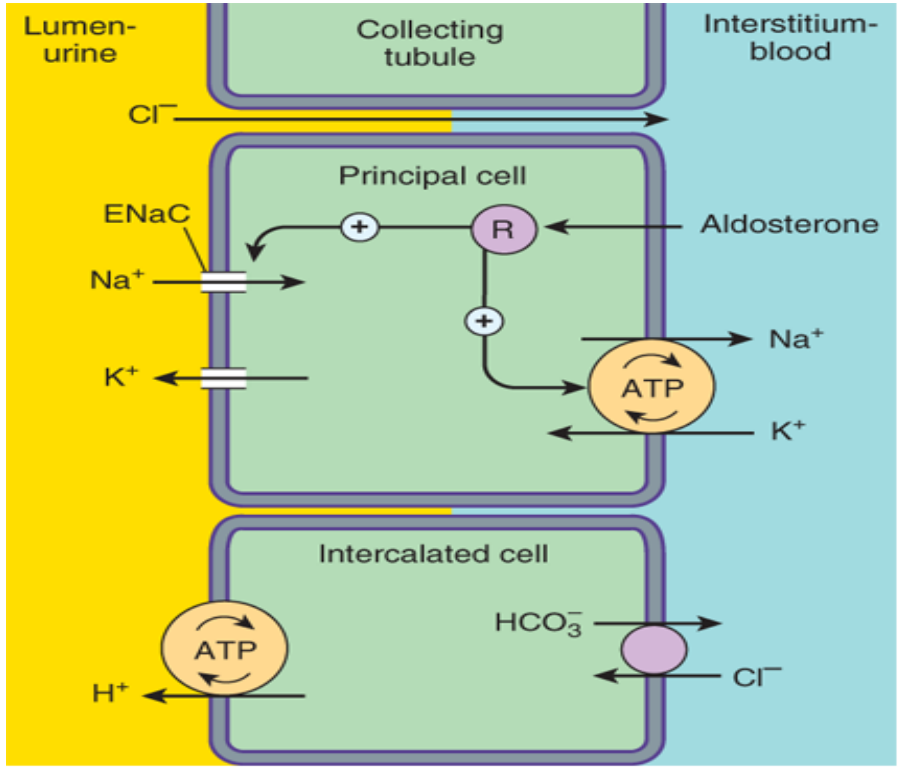
Renin-angiotensin-aldosterone system



Aldosterone

- Synthesized by adrenal cortex
- Stimulated by angiotensin II, high potassium, ACTH
- It is a Steroid

ALDOSTERONE

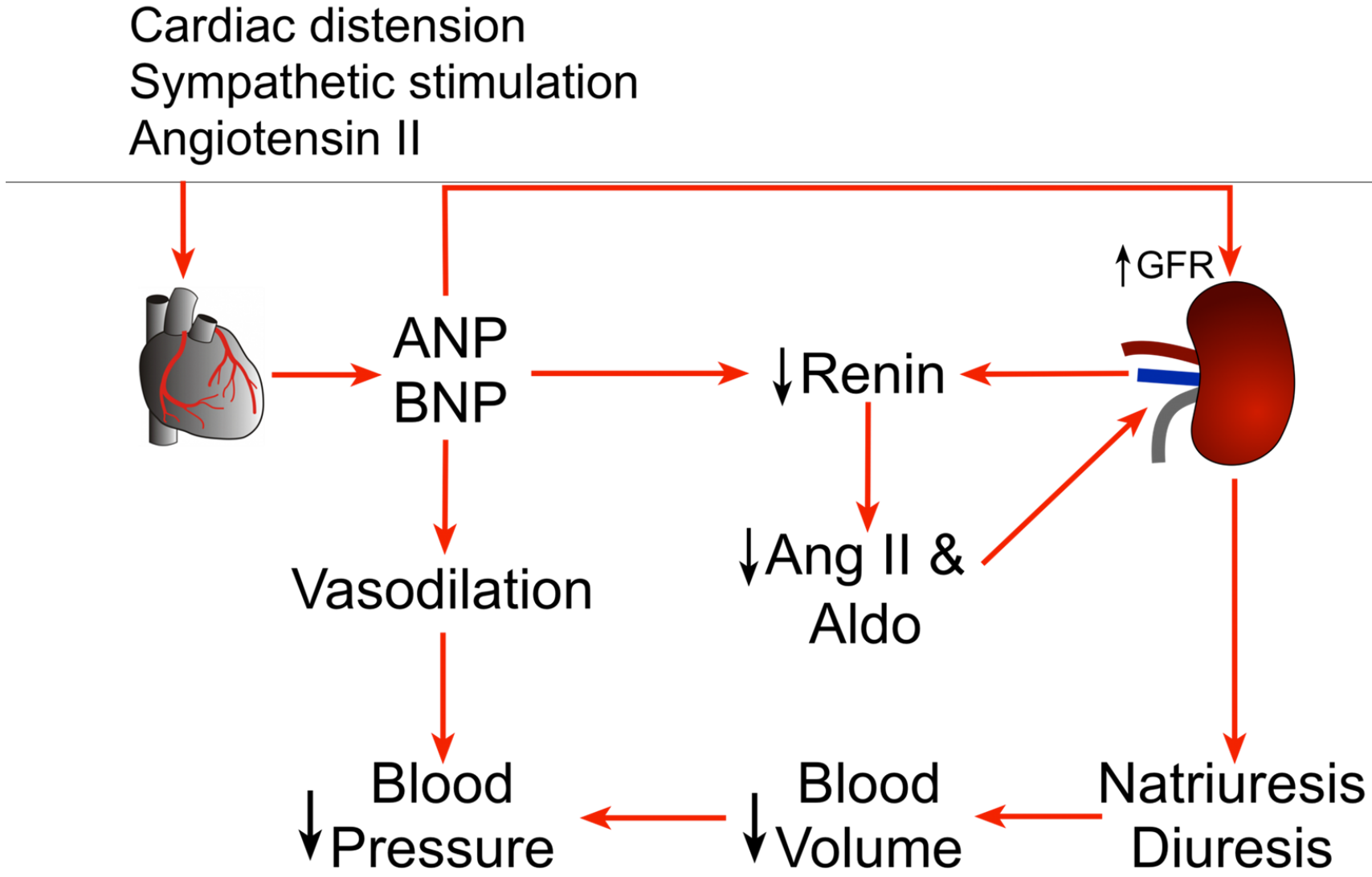


Natriuretic Peptides

- Atrial natriuretic peptides (ANP)/Brain natriuretic peptide (BNP)

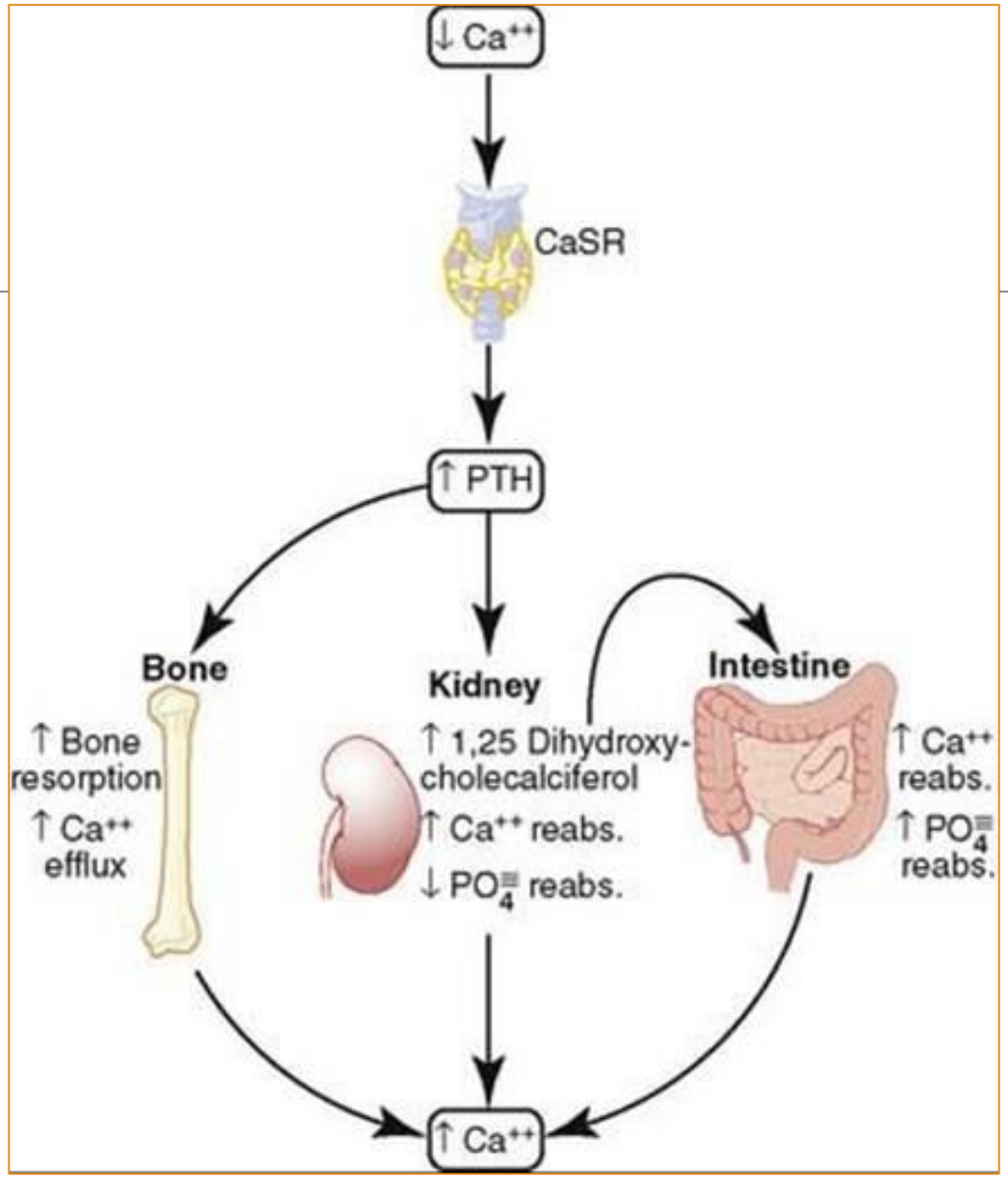
Normally BNP circulating level is 25% less than for ANP

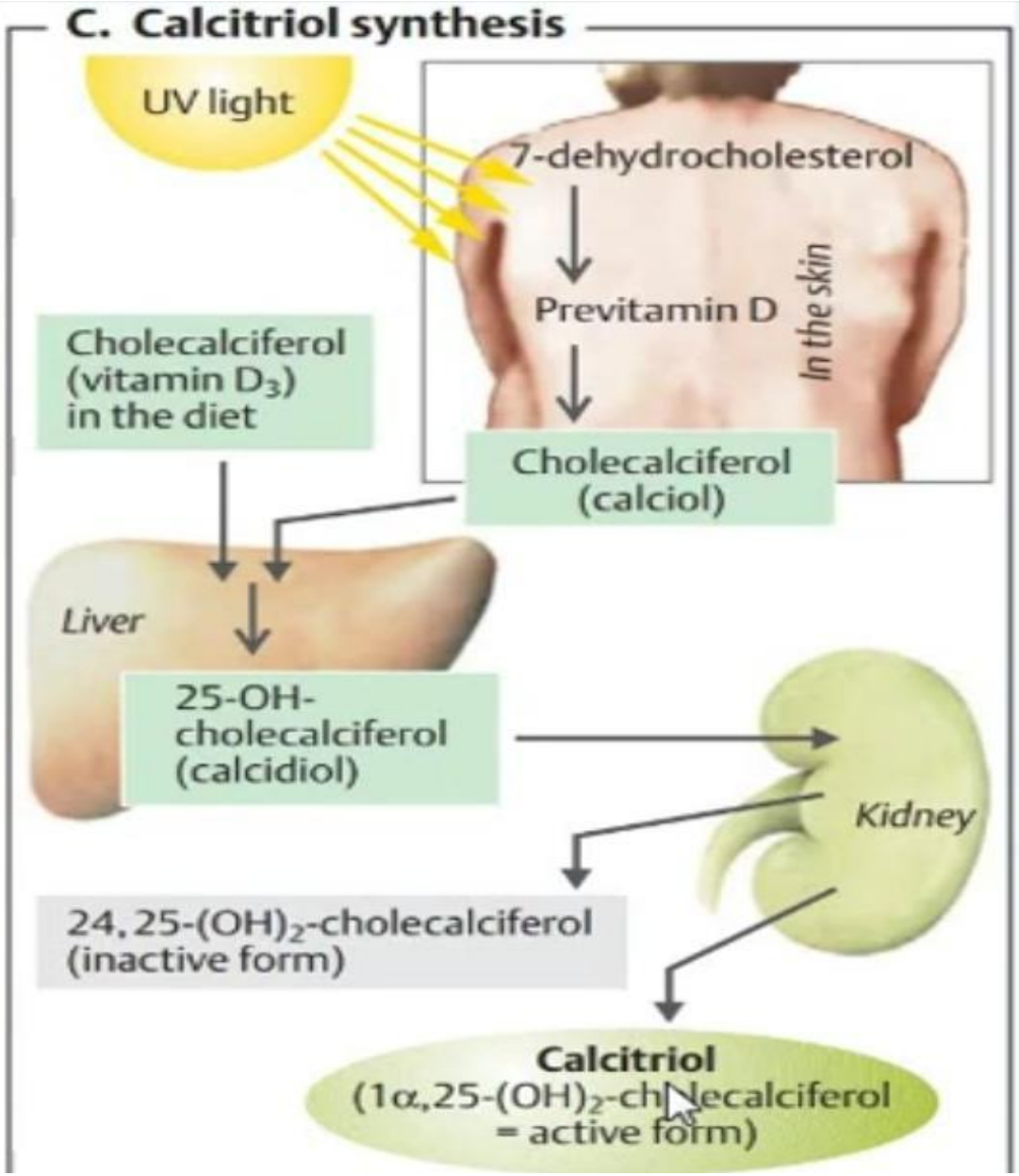
- Released in response to volume (myocyte stretch)
- Oppose actions of RAAS


Cardiac distension
Sympathetic stimulation
Angiotensin II
ANP
BNP
↓Renin
↑GFR
Vasodilation
↓Ang II &
Aldo
Blood
↓Pressure
Blood
↓Volume
Natriuresis
Diuresis

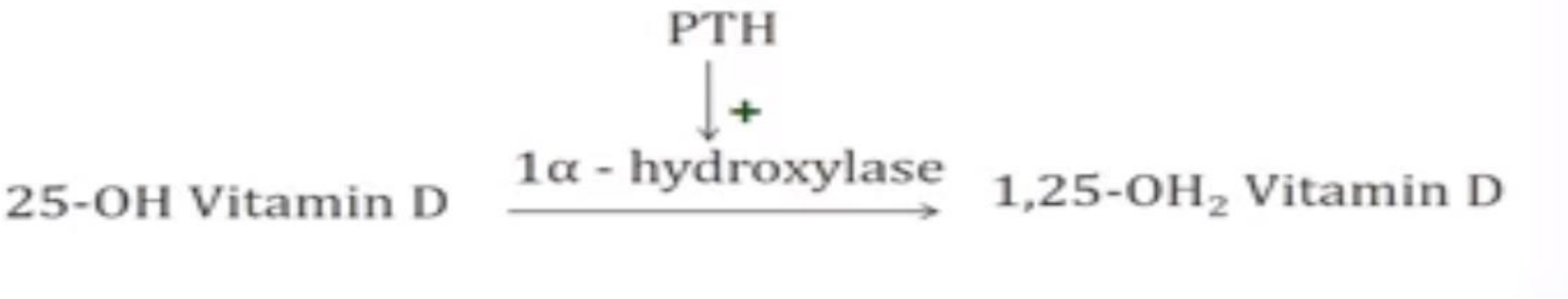
PTH

- Released by chief cells of the parathyroid
- Main stimulus is hypocalcemia
- Maintains calcium levels

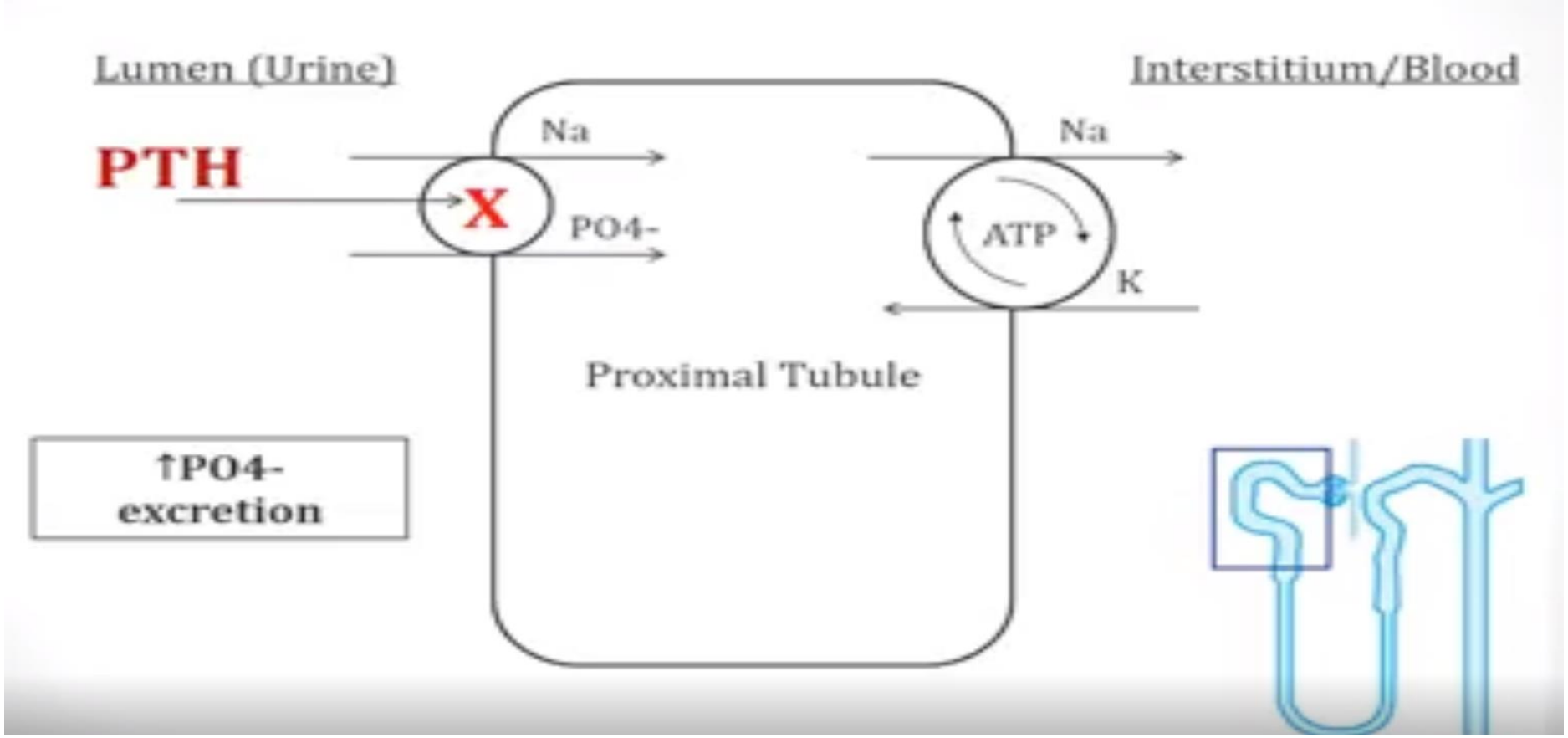



C. Calcitriol synthesis
UV light
7-dehydrocholesterol
Previtamin D
In the skin
Cholecalciferol
(vitamin D3)
in the diet
Cholecalciferol
(calciol)
Liver
25-OH-
cholecalciferol
(calcidiol)
Kidney
24, 25-(OH)2-cholecalciferol
(inactive form)
Calcitriol
(1α,25-(OH)2-cholecalciferol
= active form)

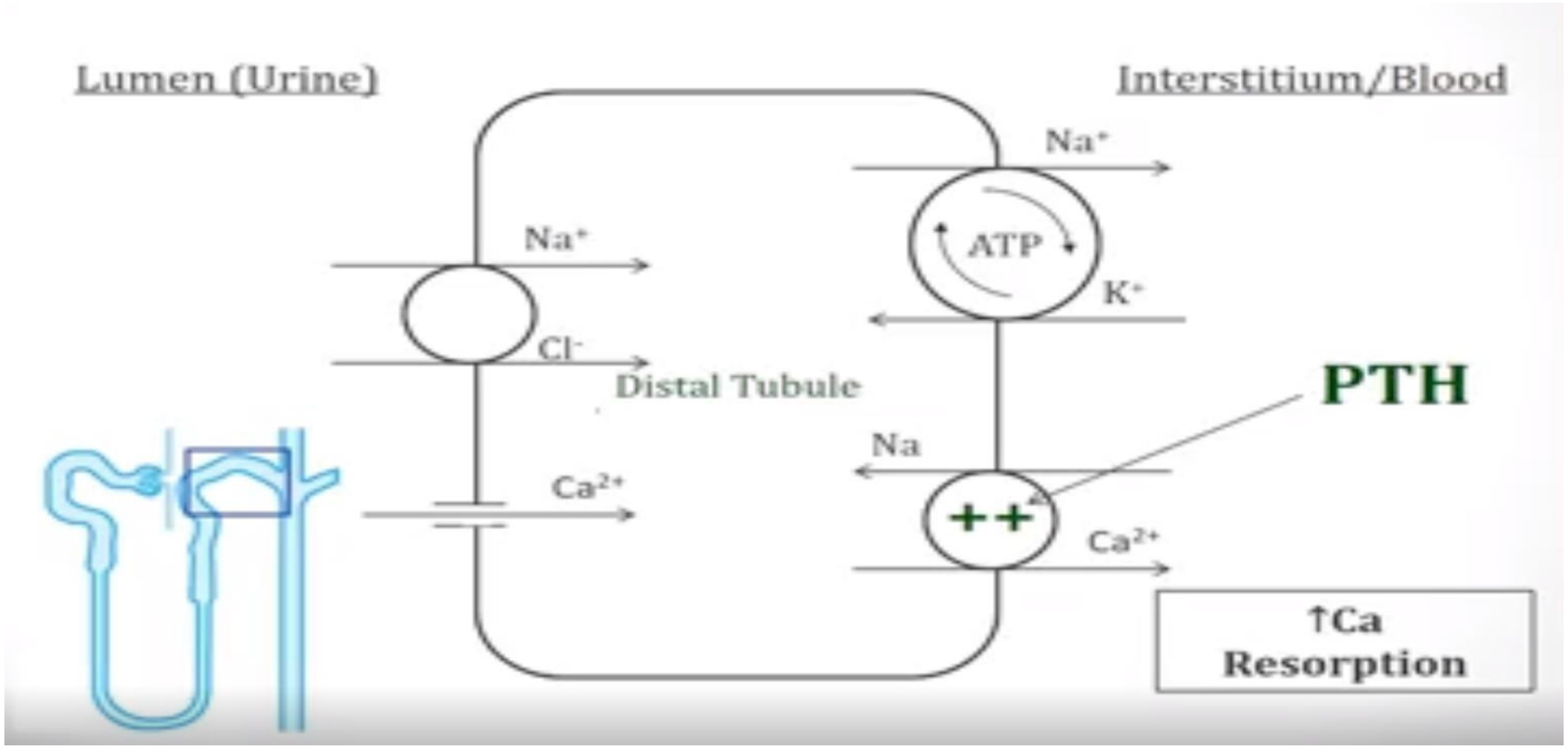
PTH (PCT)



PTH (PCT)

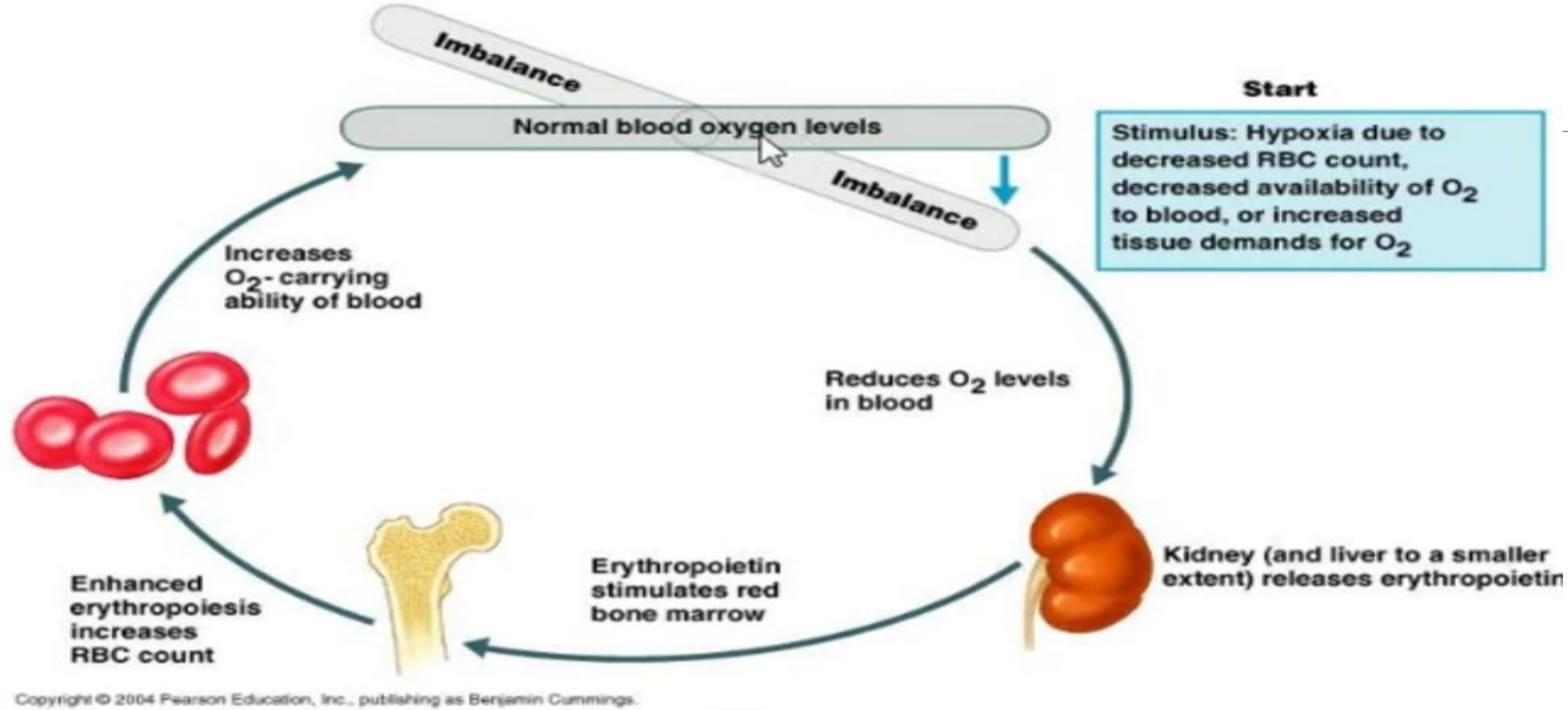

Lumen (Urine)
Interstitium/Blood
PTH
X
Na
PO4-
Na
ATP
K
Proximal Tubule
↑PO4-
excretion

PTH (DCT)


Lumen (Urine)
Interstitium/Blood
Na+
Na+
ATP
K+
Cl-
Distal Tubule
PTH
Na
Ca2+
++
Ca2+
↑Ca
Resorption

Erythropoietin

- Stimulates RBC production in bone marrow
- Made by interstitial cells of peritubular capillary
- Released in response to hypoxia



THE END

Refrences: BNB videos, USMLE step 2