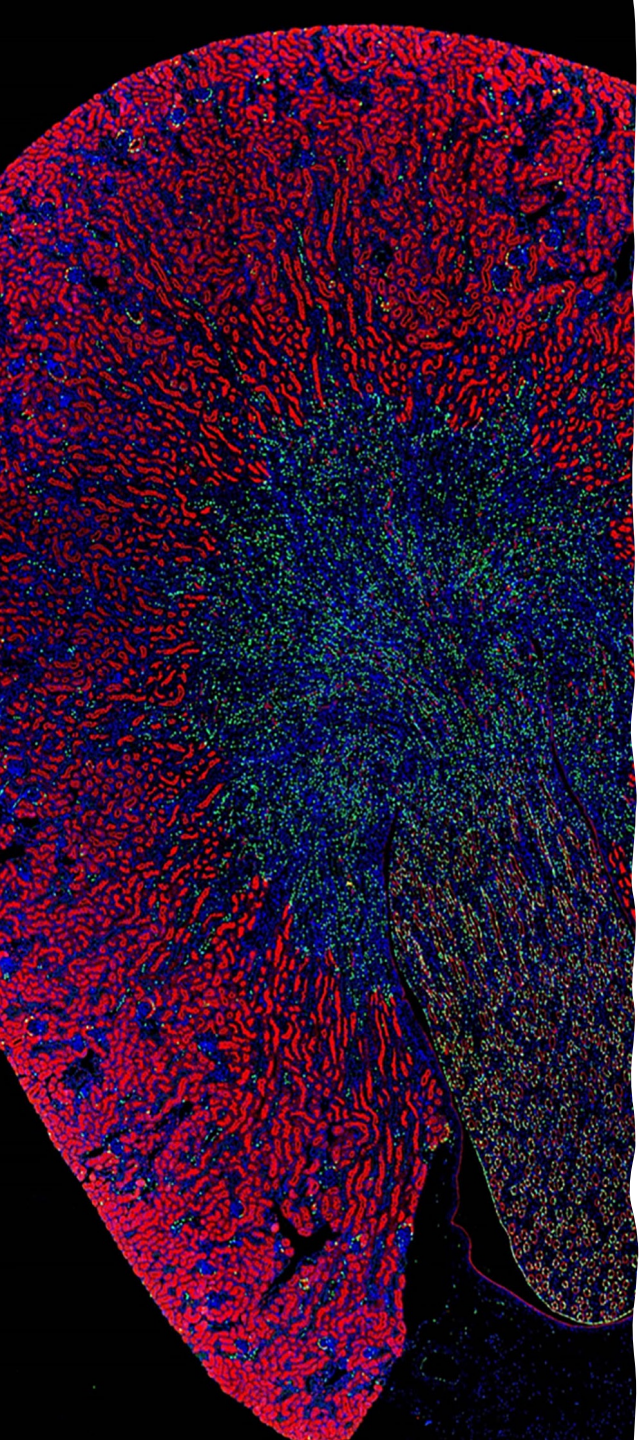
The Kidney

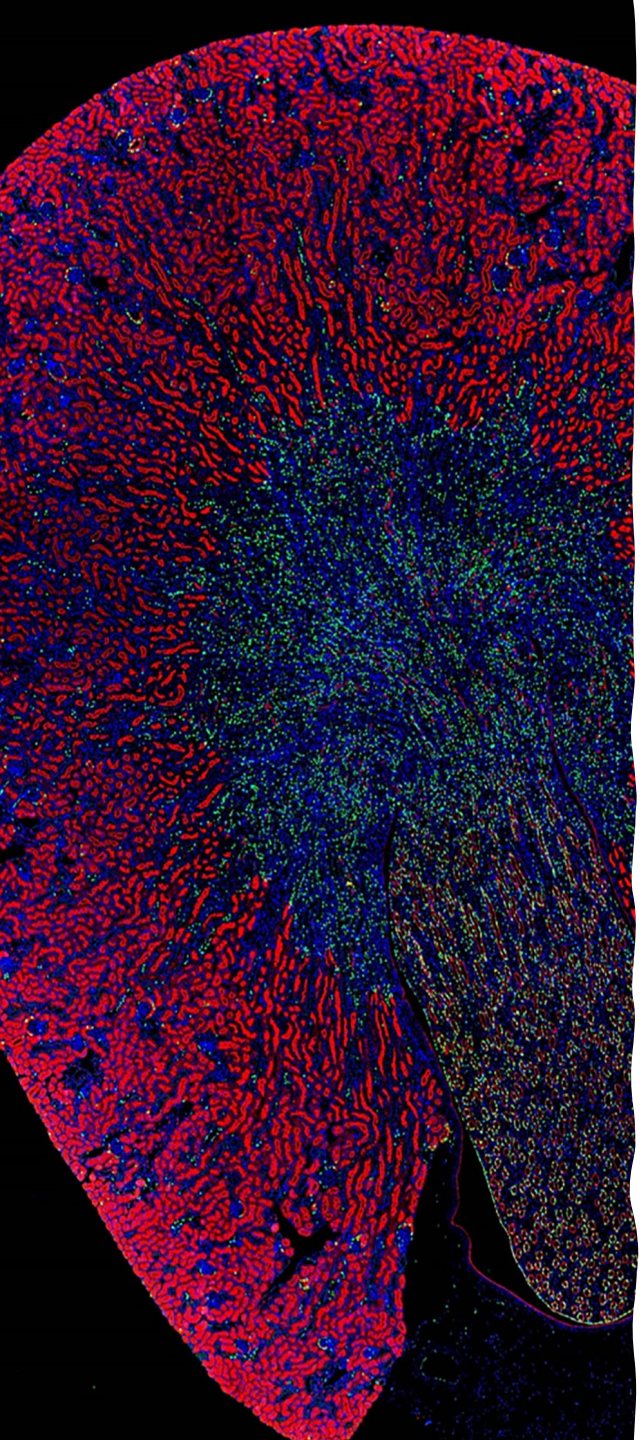
Role(s) in homeostasis

Brandon Roberts, Ph.D.



Learning Objectives

1. Summarize the functions and basic structure of the kidney
2. Identify the three processes of urine formation
3. Explain how each structure of the nephron contributes to water-salt balance



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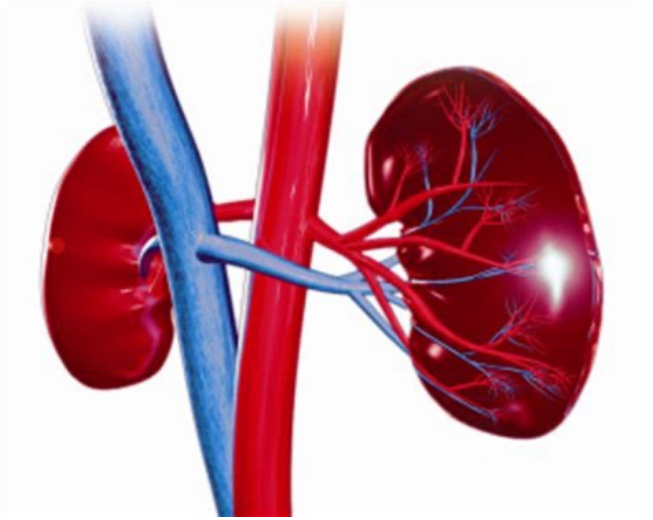
Functions of the Kidney

- **Remove waste** products from the body
- Maintain **acid-base** (pH) and **water-salt** balance
- Regulate **blood pressure**
- Promote production of **red blood cells**
- Activate **vitamin D**

Maintain **homeostasis** despite changes in endogenous production and dietary intake



Components of Homeostasis

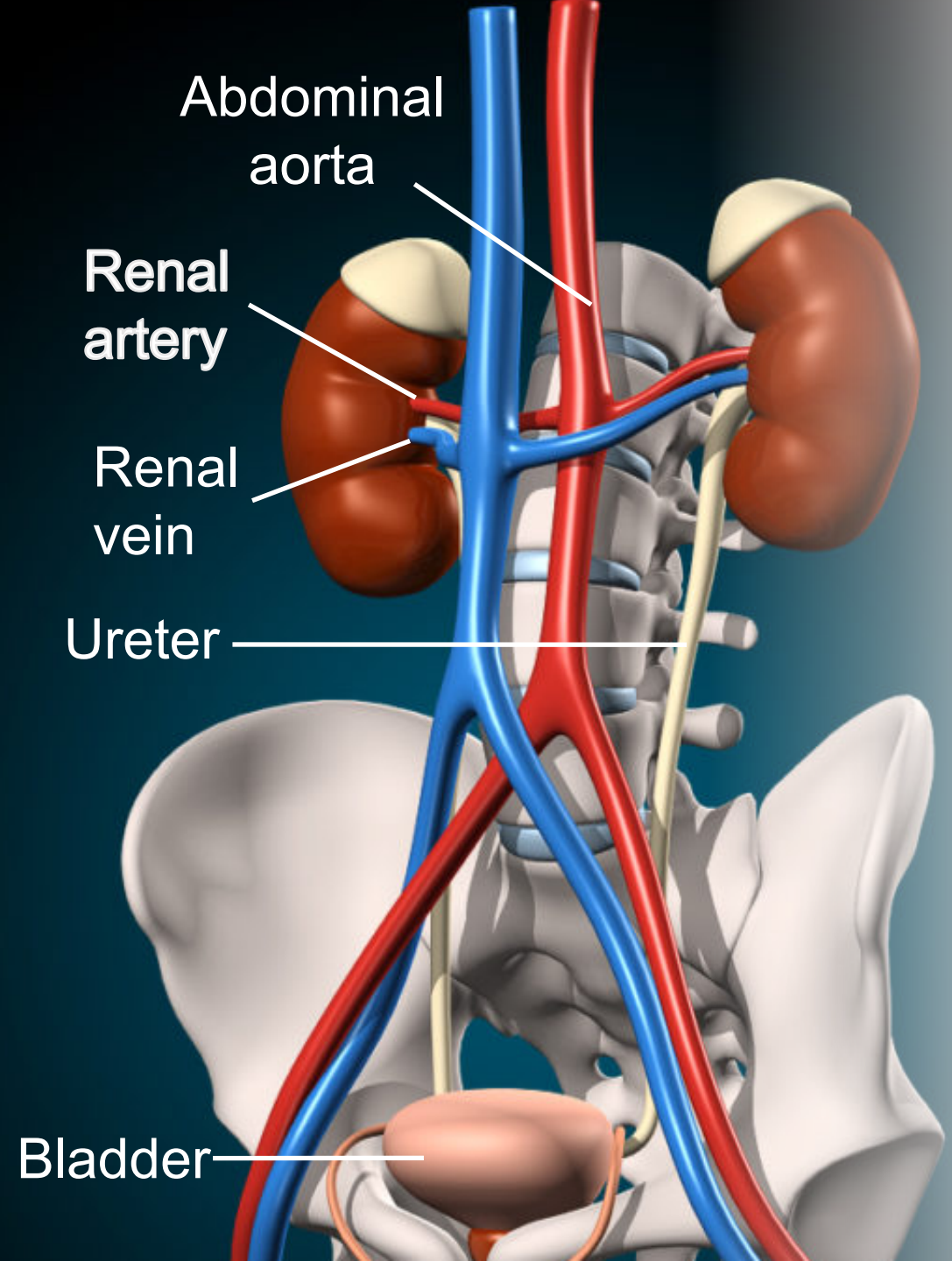
Electrolytes - sodium, potassium, chloride

Minerals - calcium, phosphorus, magnesium

Water - (osmolality)

Acid-base – carbonic acid and bicarbonate

Waste material - urea (protein), creatinine (muscle), uric acid (nucleic acids)



Renal system

Input:

- Circulation

Output:

- Circulation
- Urinary tract

Renal Clearance

$$C_s = \frac{U_s \times V}{P_s}$$

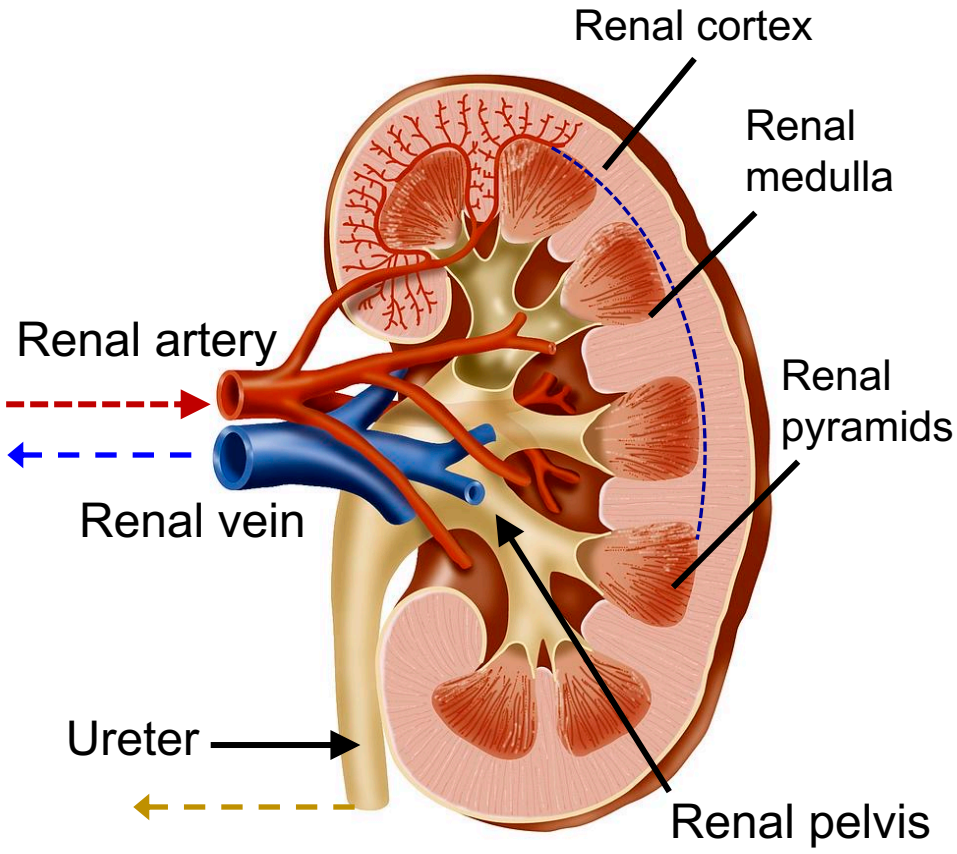
Input:
- Circulation

Output:
- Circulation
- Urinary tract

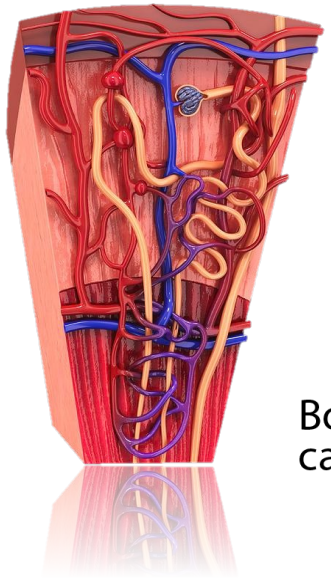
C_s – Clearance of substance
U_s – Urine concentration of substance
P_s – Plasma concentration of substance
V – Urine flow rate

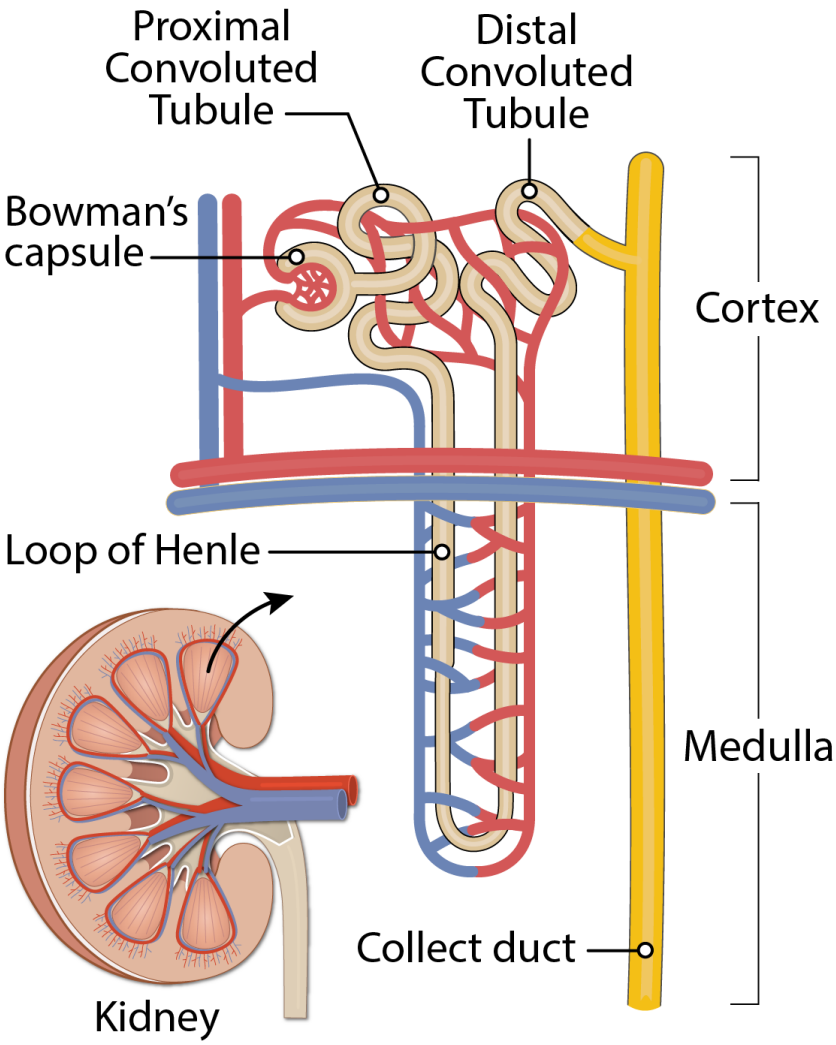
Kidney Structure

- **Renal cortex** - outer layer that receives blood from the **renal artery**
- **Renal medulla** – inner layer that consists of the **renal pyramids**
- **Renal pelvis** - a central waste collection space that is continuous with the **ureter**



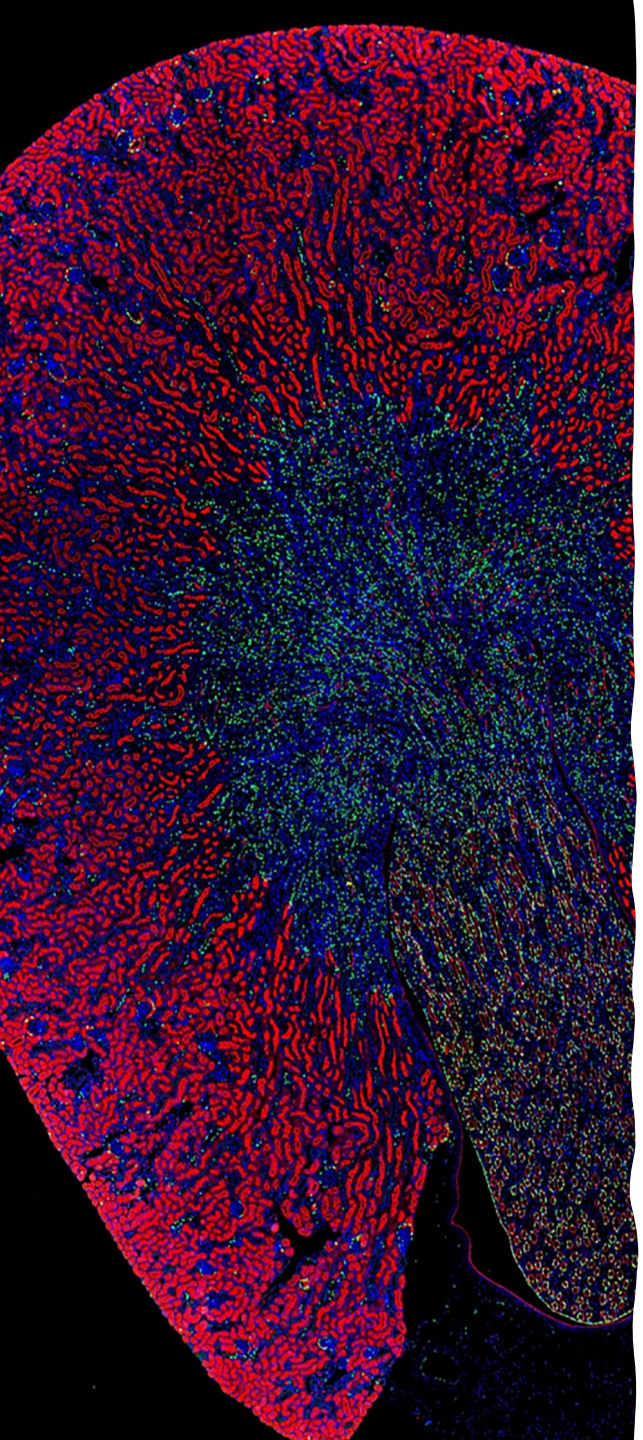
Nephron





Nephron - microscopic filtration unit of kidneys

- Filter blood and produce urine
- Several nephrons empty urine into one **collecting duct**
- The collecting ducts empty into the **renal pelvis**



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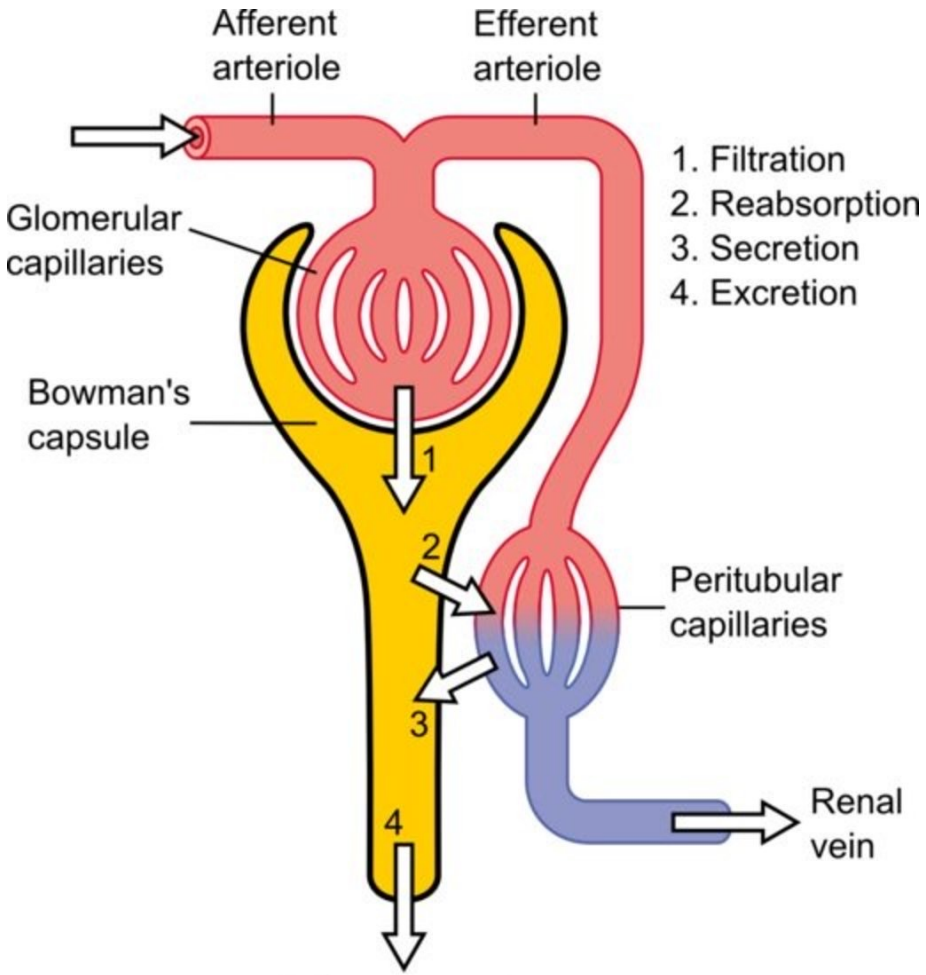
Three processes of urine formation



Excretion = Filtration – Reabsorption + Secretion

Three processes of urine formation

Glomerular Filtration:

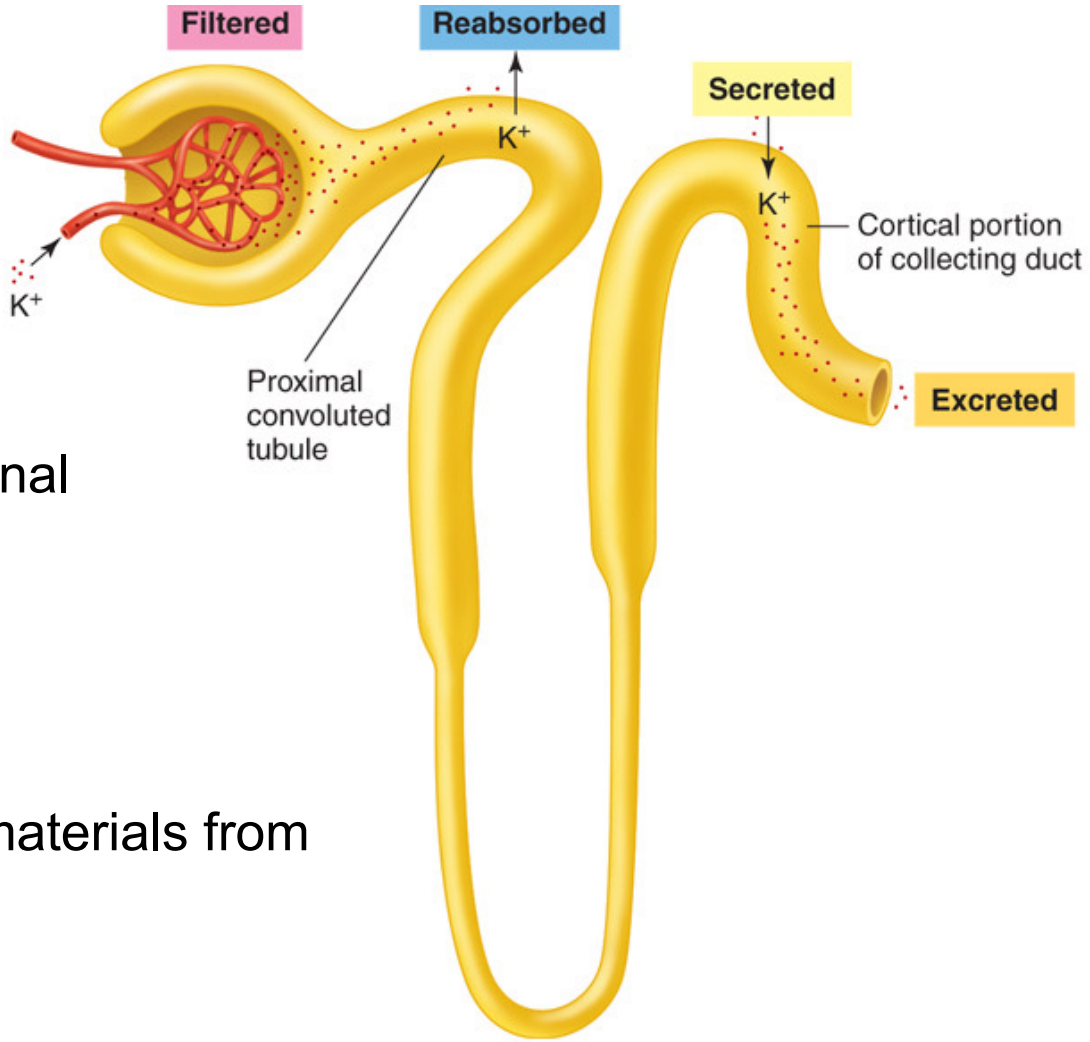
movement of materials from glomerulus into nephron

Tubular Reabsorption:

movement of nutrients from renal tubules back into blood

Tubular Secretion:

movement of wastes/excess materials from blood into renal tubules



Glomerular filtration

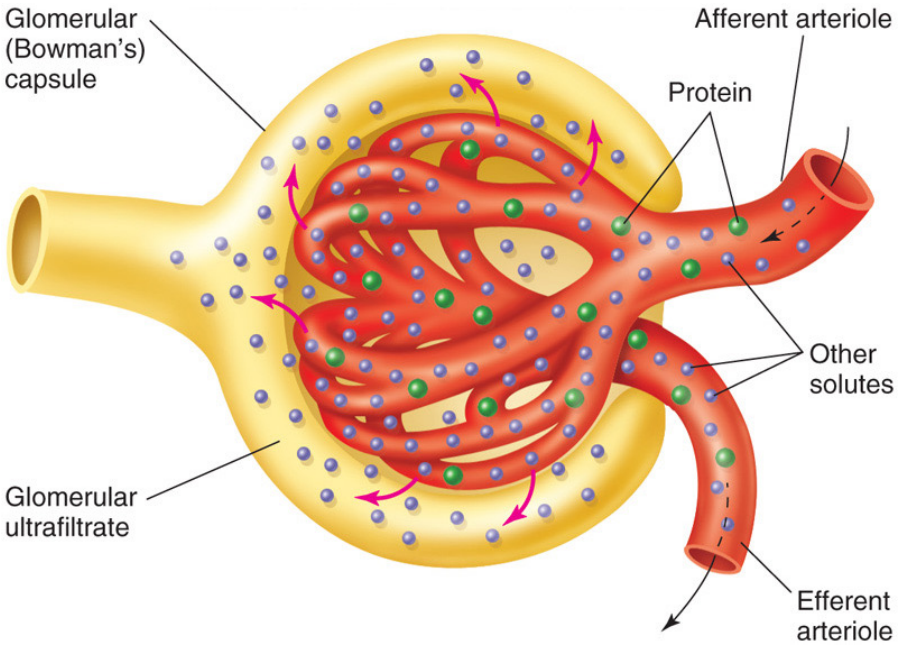
Glomerulus

fenestrated capillaries that pass:

- Electrolytes
- Glucose
- Amino acids
- Water

basement membrane that passes:

- (+) charged molecules
- Neutral charged molecules



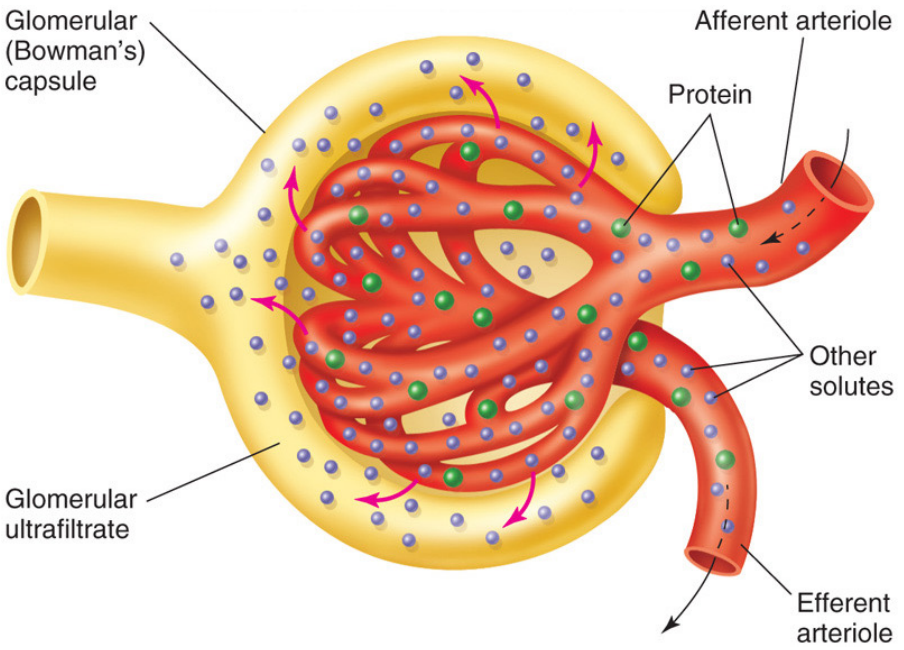
Results in production of **ultrafiltrate**

Glomerular filtration

~ 180 L/day of **ultrafiltrate** produced; only 1–2 L of urine excreted/24 hours

Urine volume varies according to needs of body

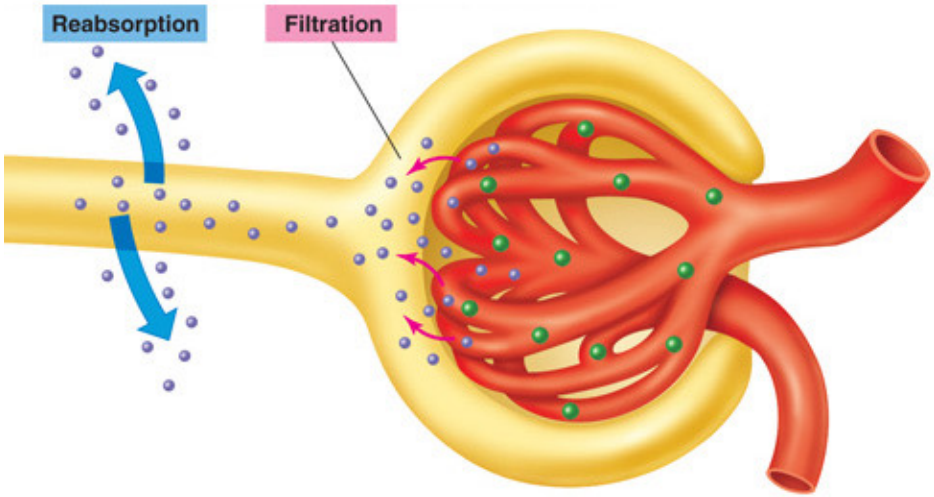
Majority of ultrafiltrate undergoes **tubular reabsorption**



Tubular reabsorption

- **Reabsorption** – process by which water and salts are move from the nephron back into the blood

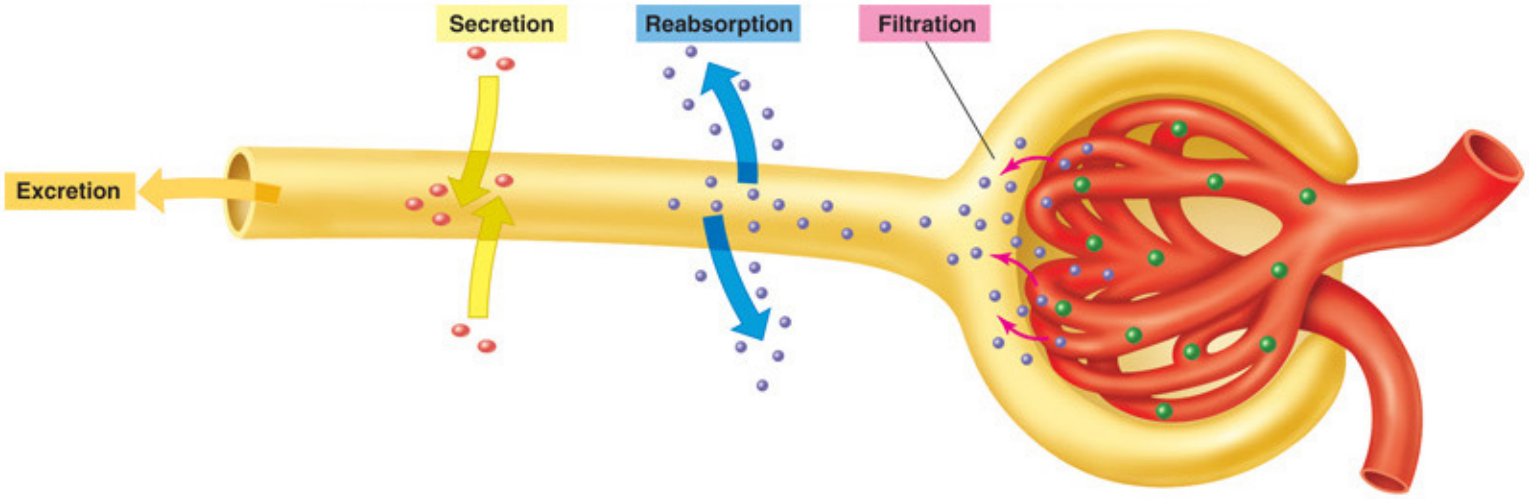
- Reabsorption decreases renal clearance



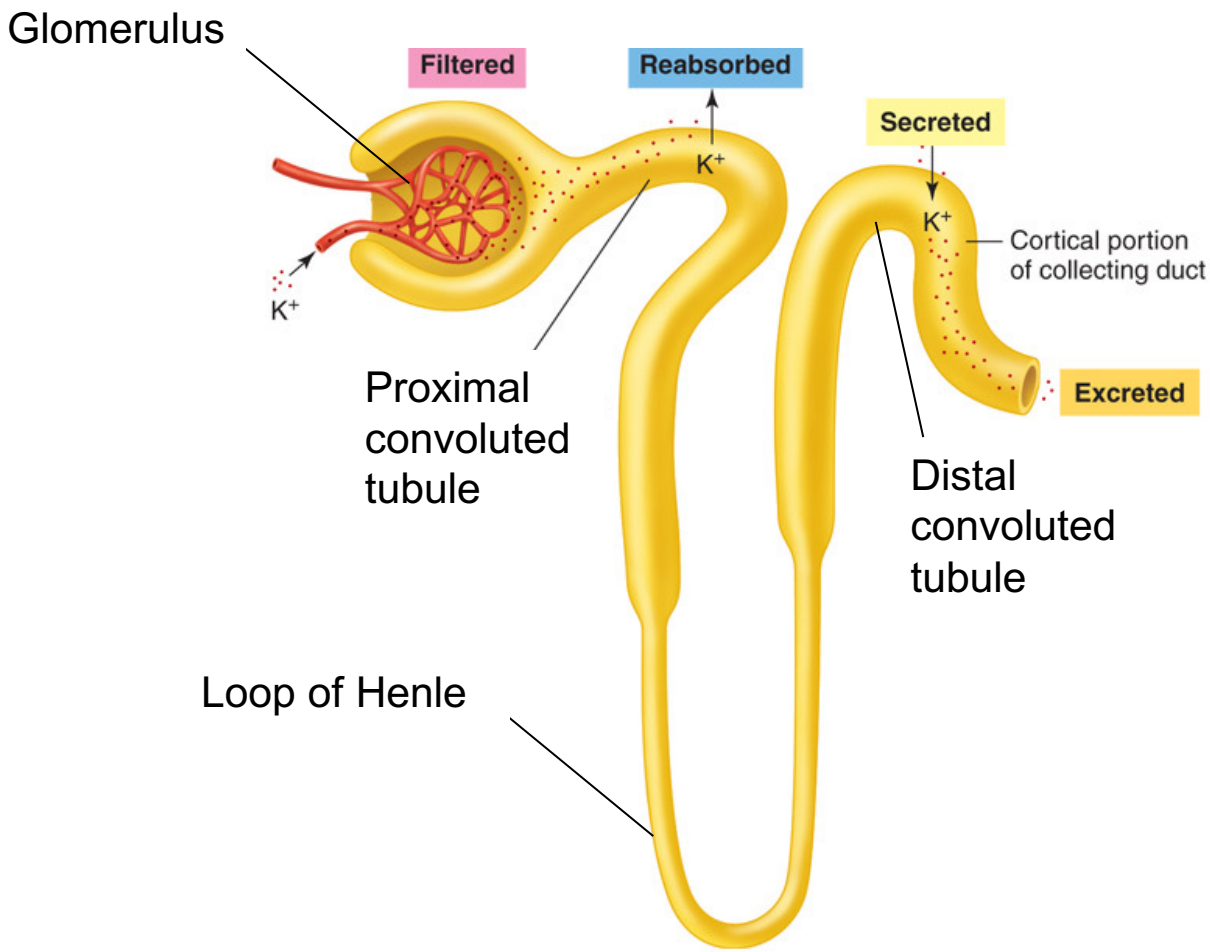
Tubular secretion

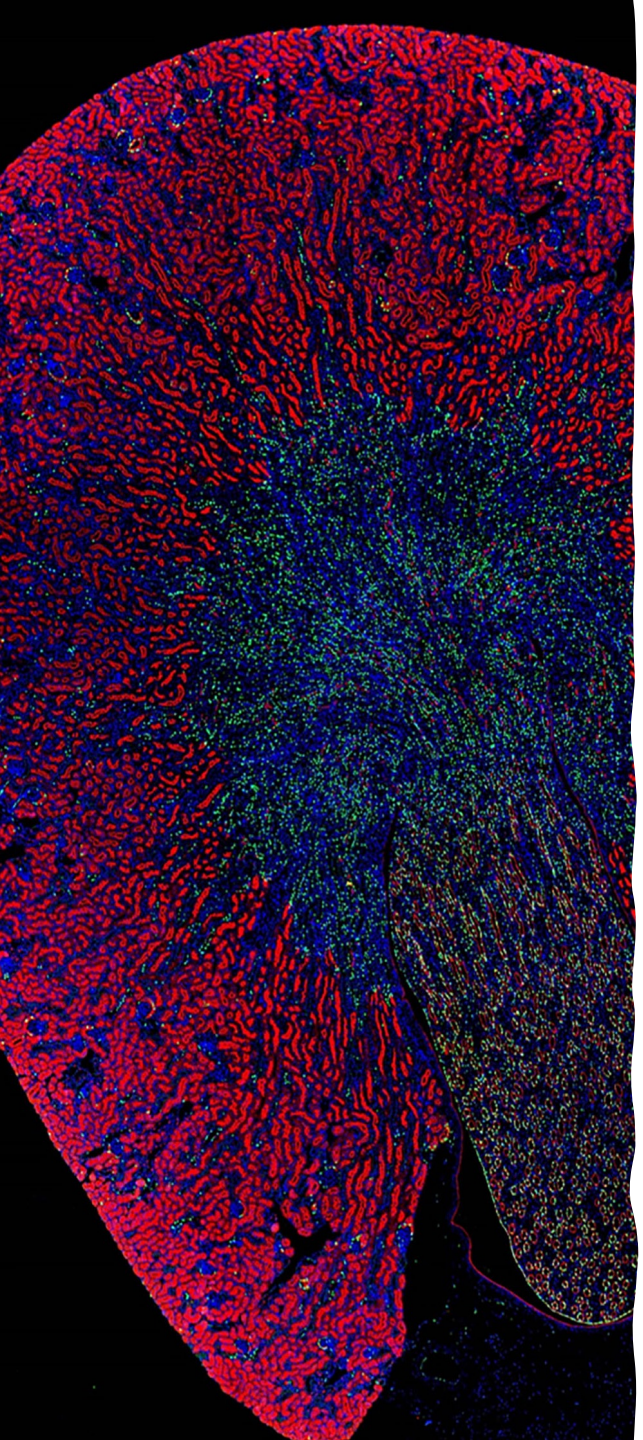
- **Secretion** is opposite of reabsorption - substances are transported into tubule and **excreted**

- Reabsorption decreases renal clearance; secretion increases clearance



Three processes of urine formation





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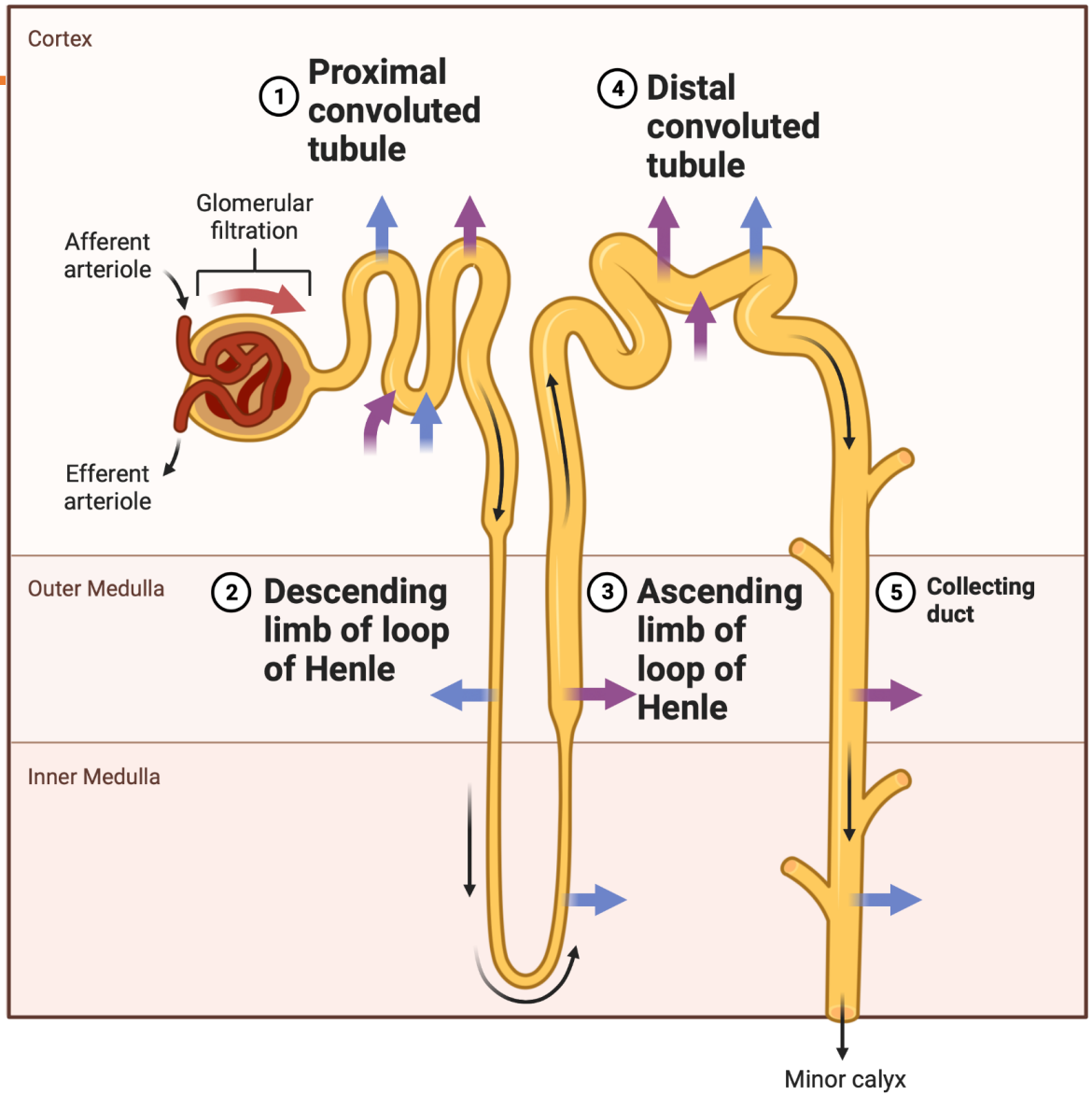
Kidneys regulate water-salt balance

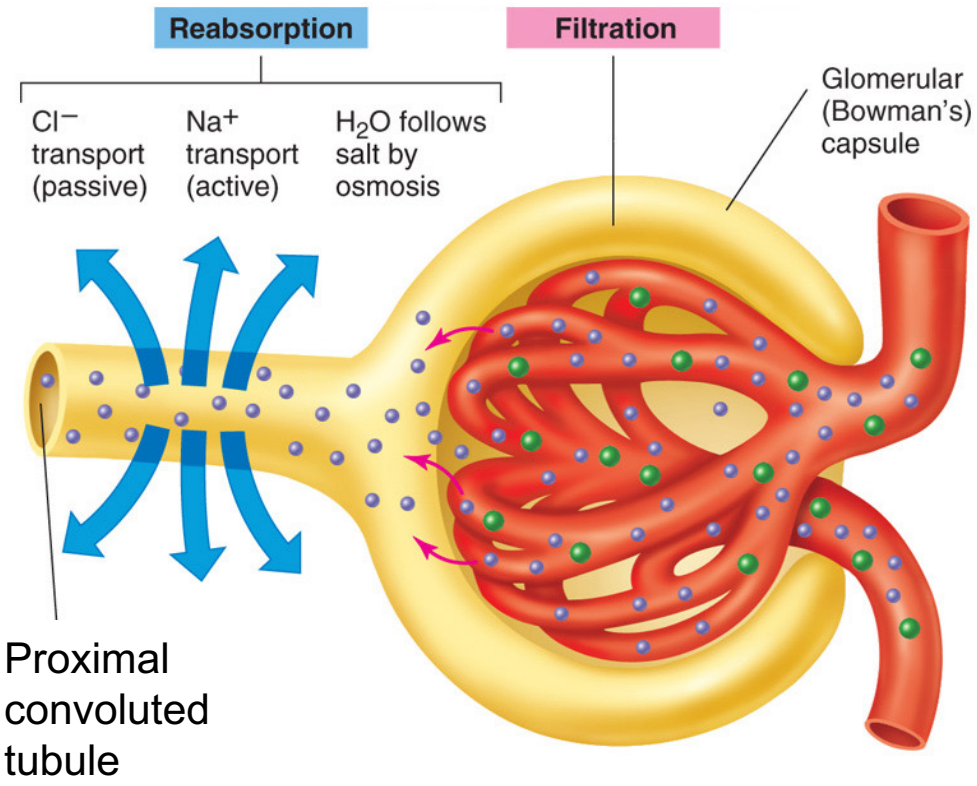


Proximal convoluted tubule

Ultrafiltrate is isosmotic to blood (~300 mOsm/L)

Reabsorption of H_2O by osmosis cannot occur without **active transport** (AT) of Na^+

- Loss of (+) charges causes Cl^- to passively follow
- Water then follows salt by osmosis



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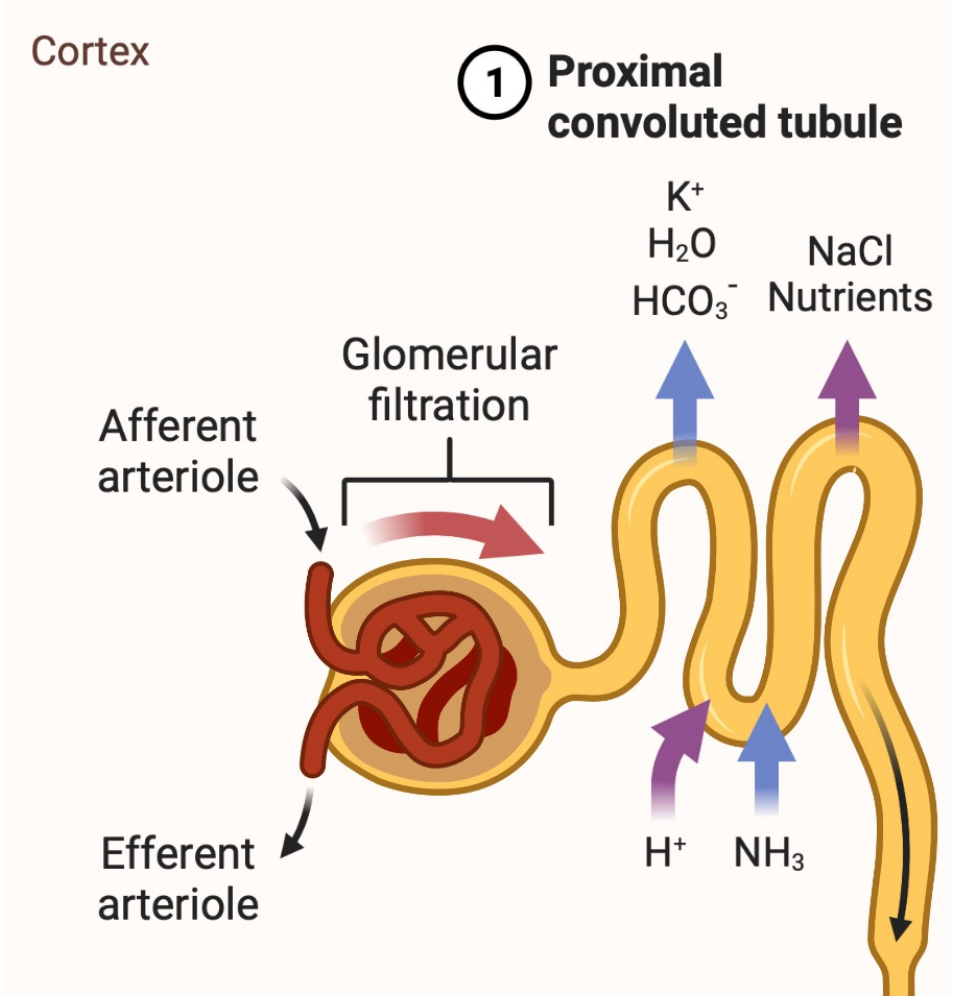
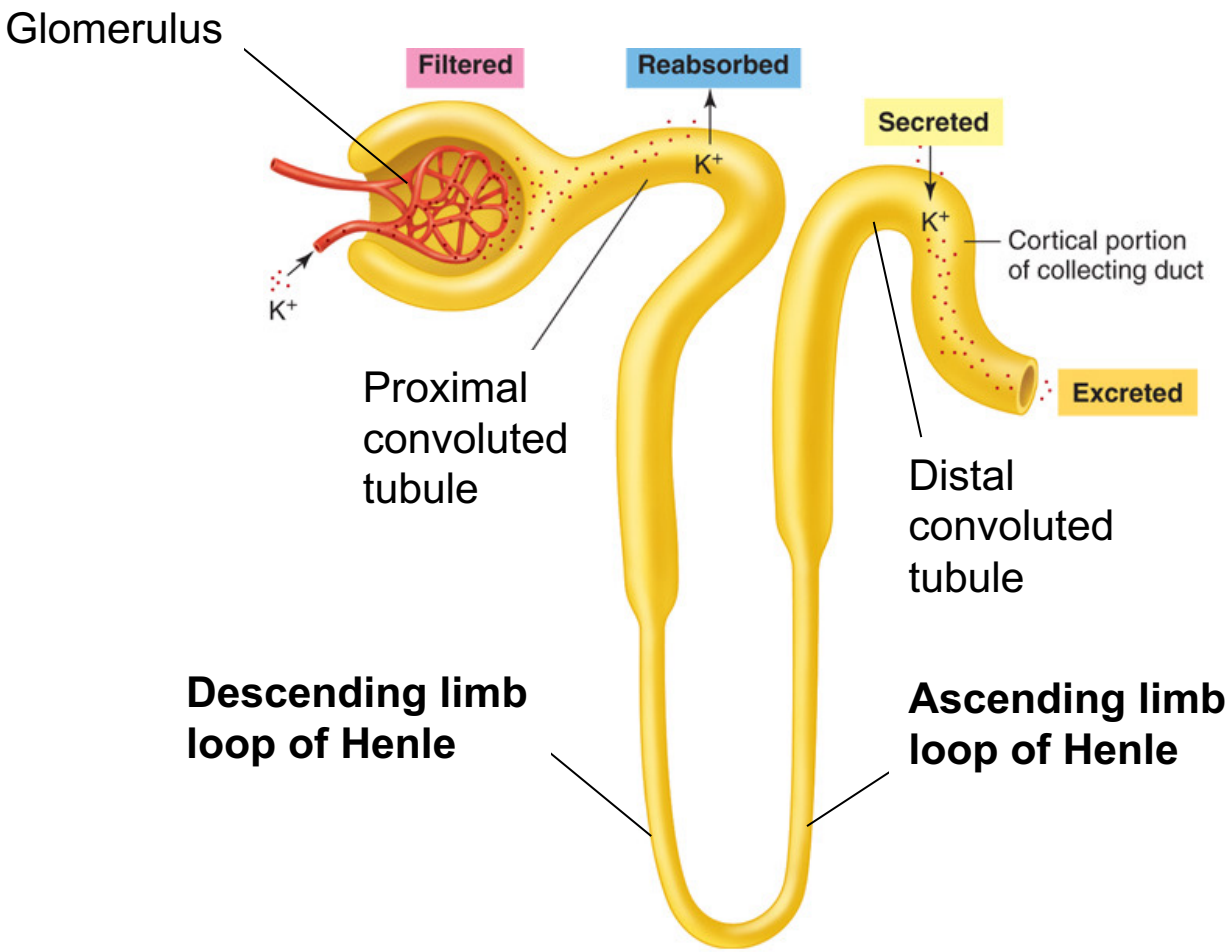
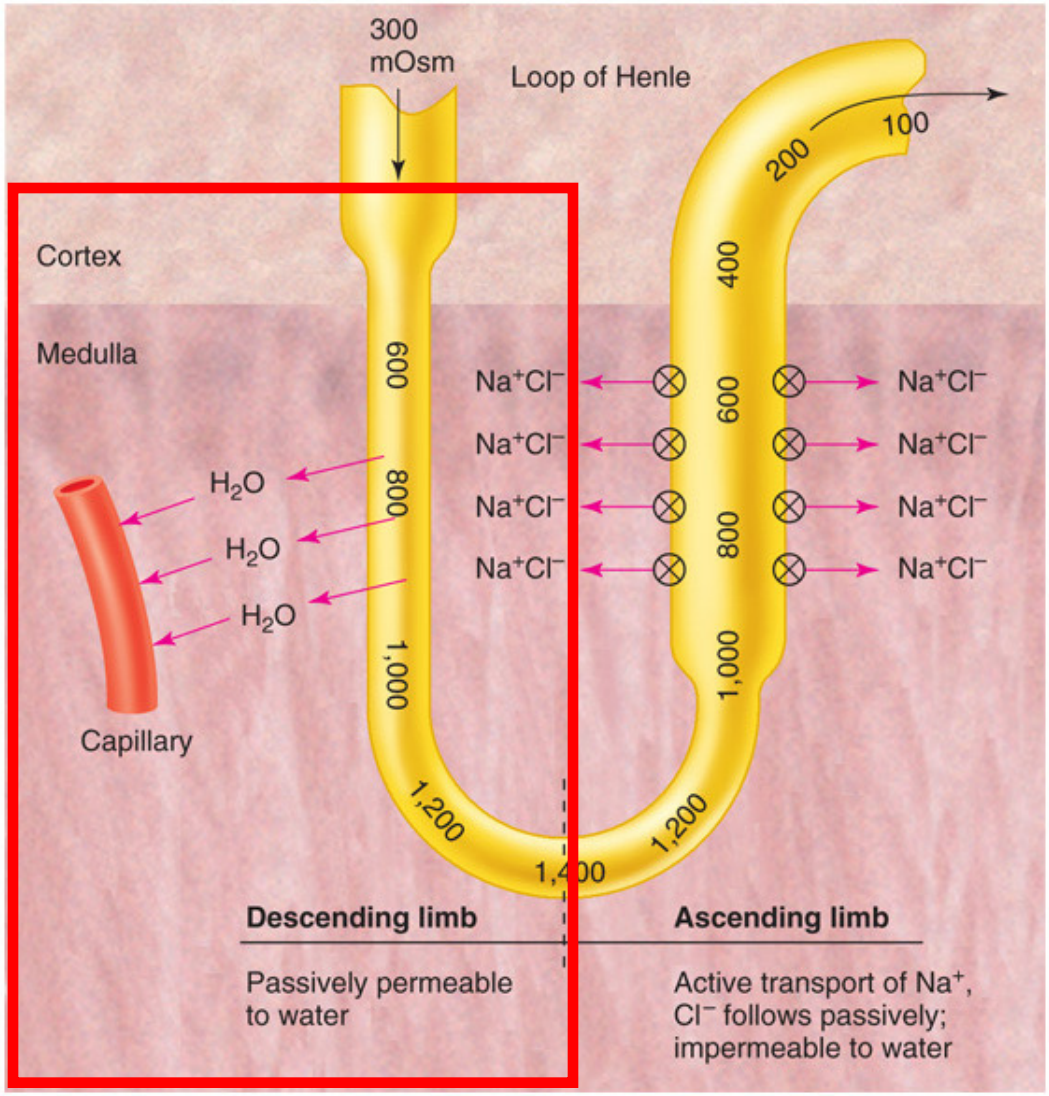


Loop of Henle



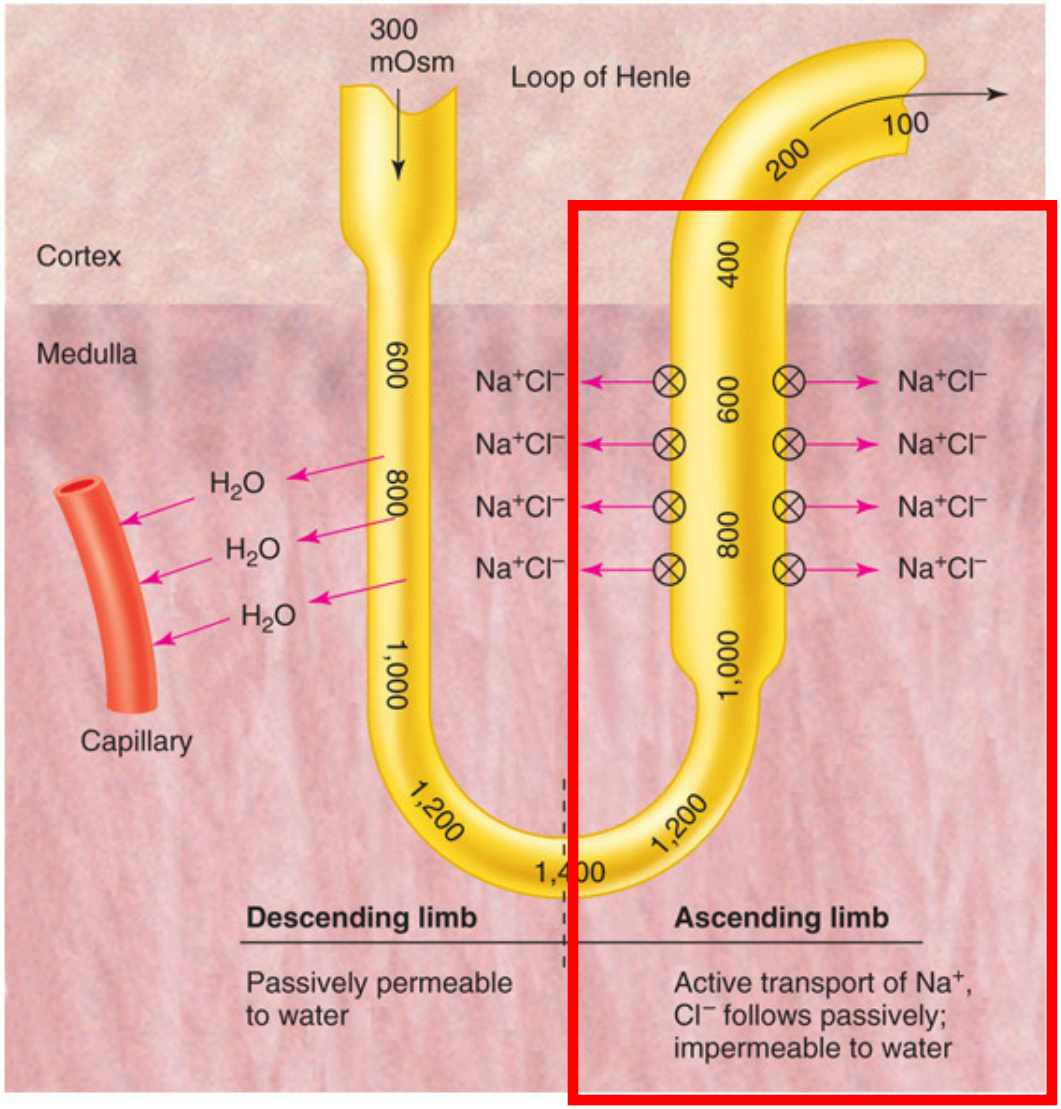
Descending Limb Loop of Henle

- Is permeable to H_2O
- Is impermeable to, and does not actively transport, salt
- Deep regions of medulla are **hypertonic**
- H_2O diffuses out of filtrate into interstitial fluid
- H_2O is then collected by capillaries

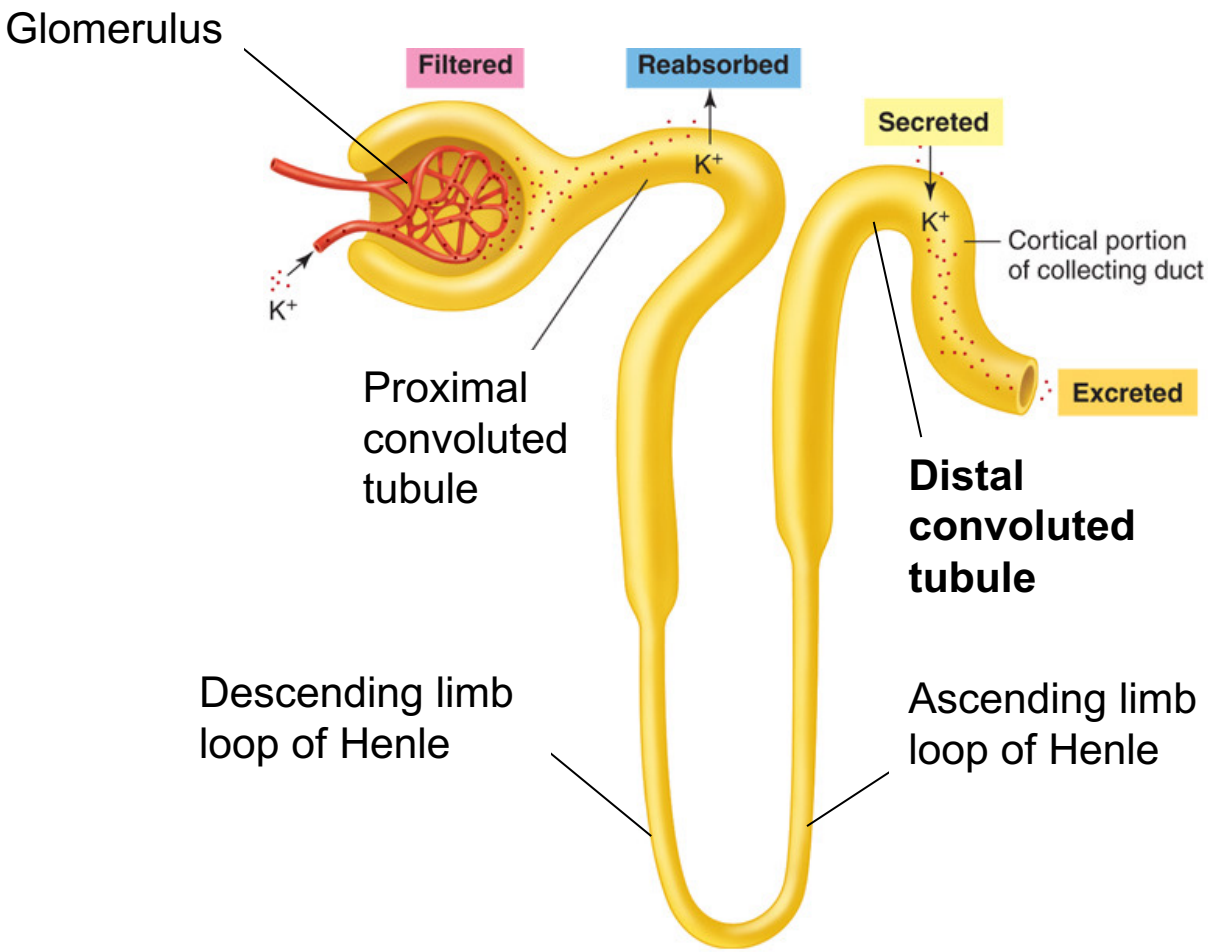


Ascending Limb Loop of Henle

- Impermeable to H_2O, but **permeable to salt**
- thick walls provide **active transport** of salt out of filtrate
- AT of salt causes interstitial fluid to become hypertonic to ultrafiltrate



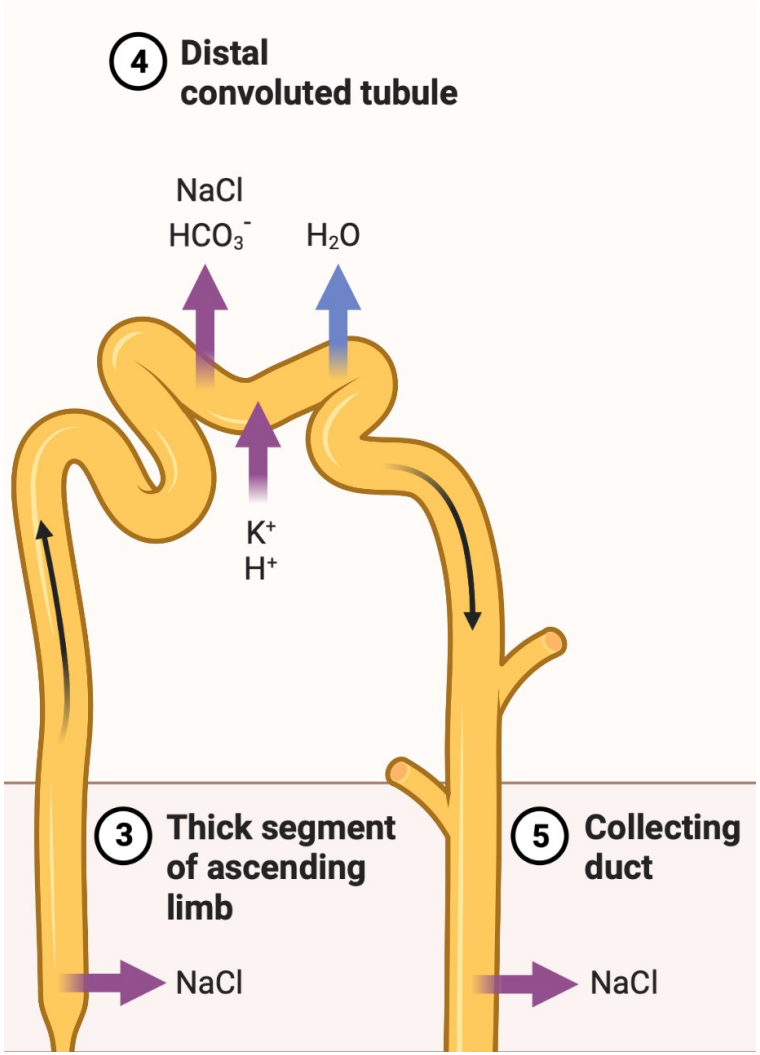
Distal convoluted tubule

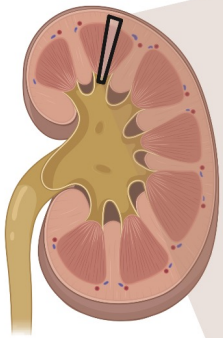


Distal convoluted tubule

Primary function:

- **Secretion** from blood plasma to filtrate
- Secreted ions:
  - Potassium (K^+)
  - Acid (H^+)
- Reabsorption of water influenced by hormones
- Empties into **collecting duct**





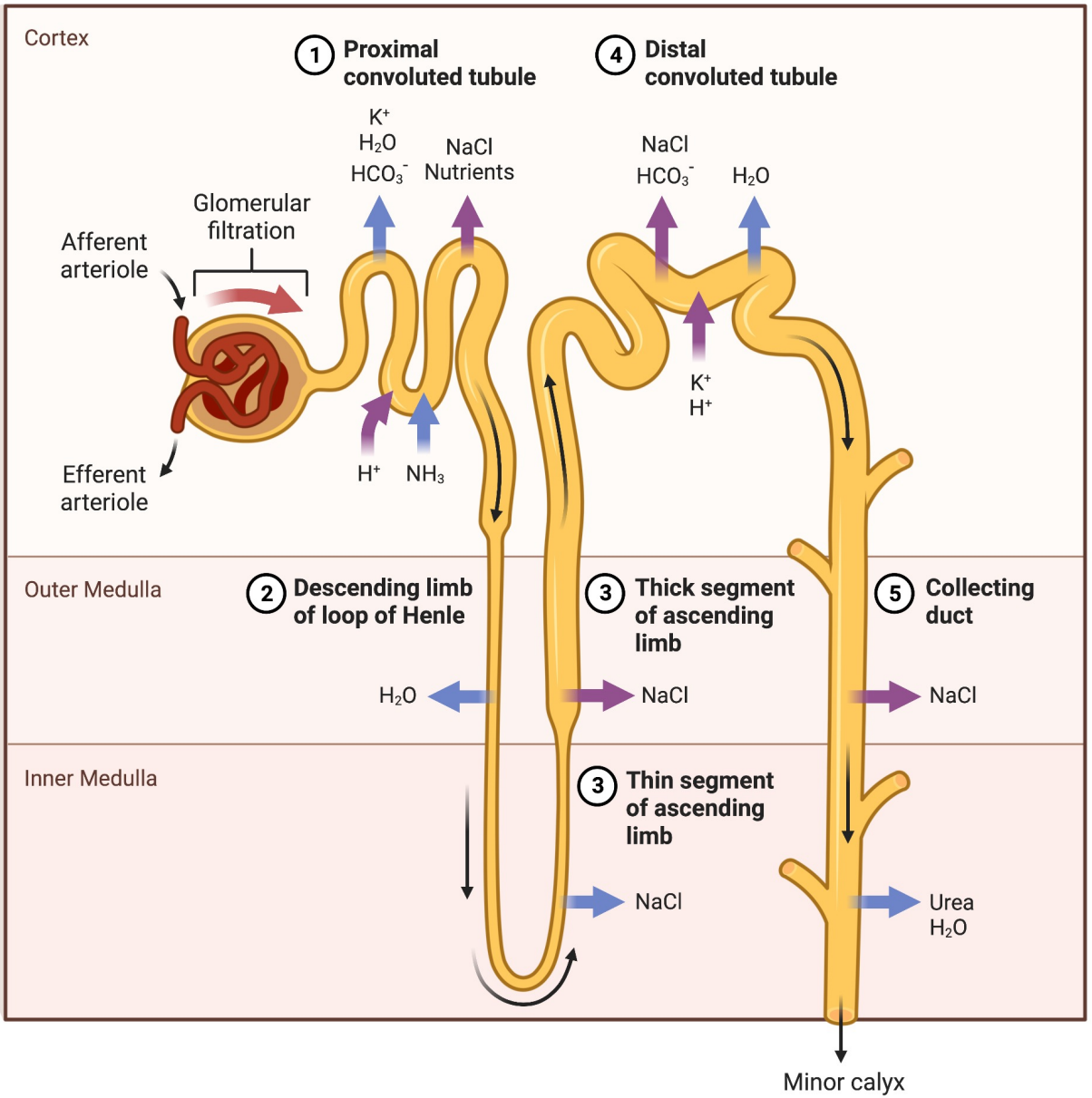
Filtration

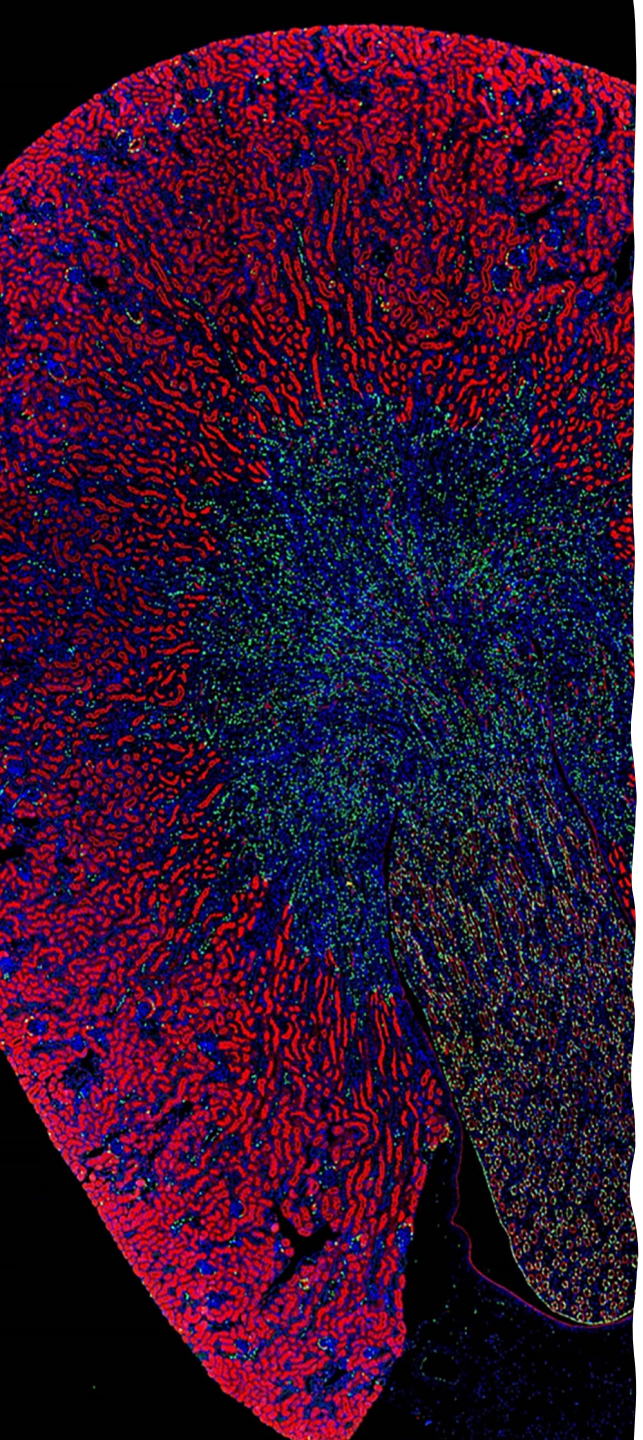
- H_2O
- Salts (NaCl, etc.)
- HCO_3^-
- H^+
- Urea
- Glucose
- Amino acids
- Some drugs

Reabsorption and secretion

Active transport

Passive transport





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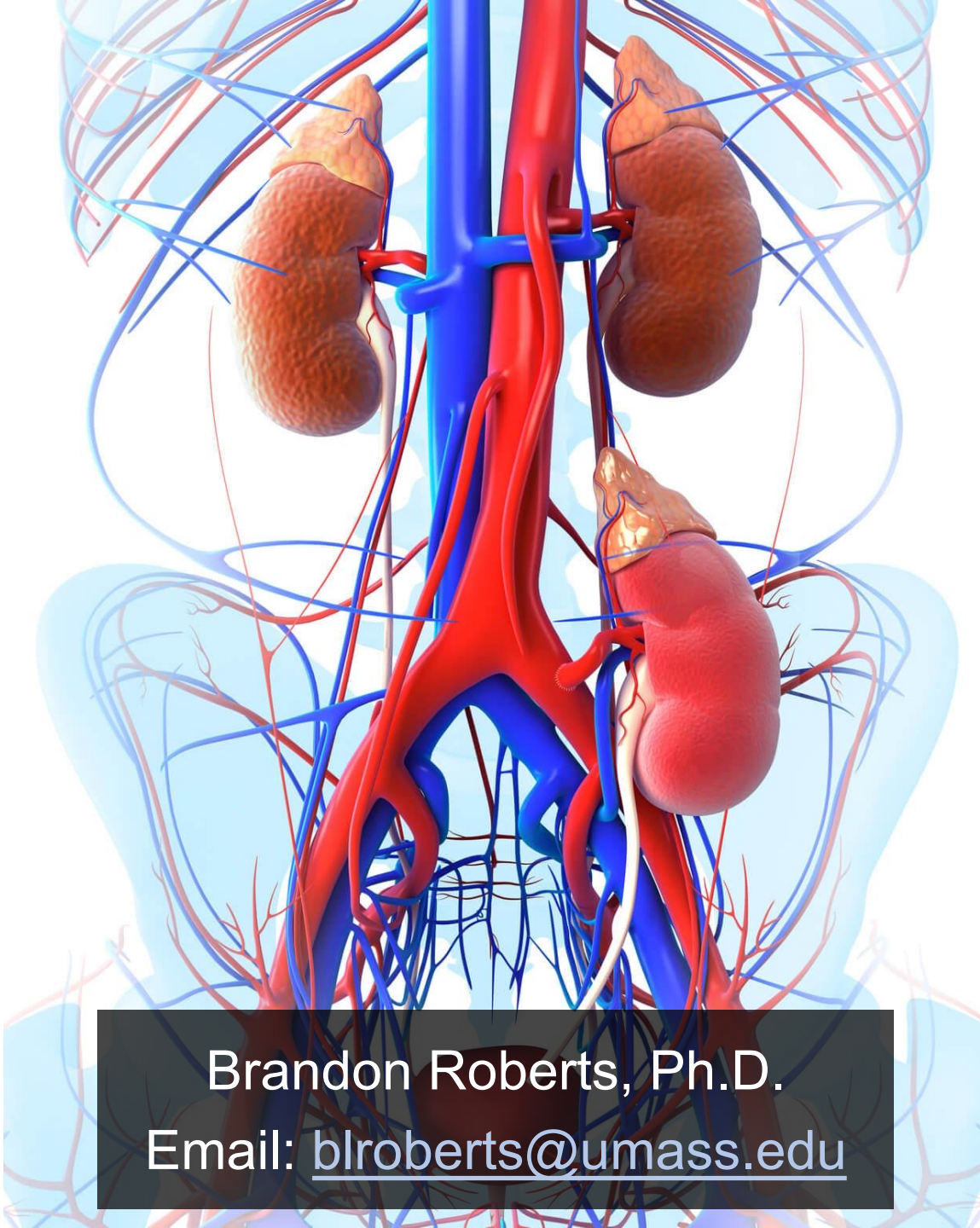

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Email: blroberts@umass.edu

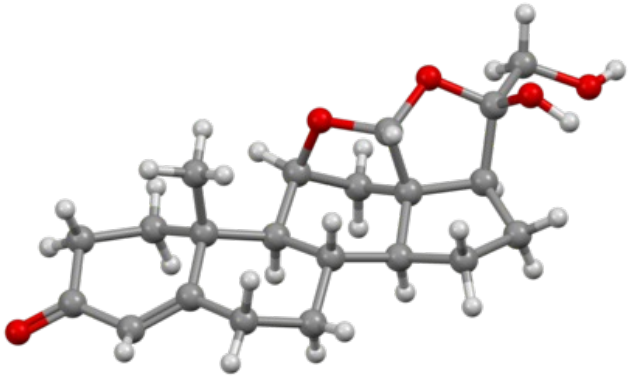
Supplemental Material

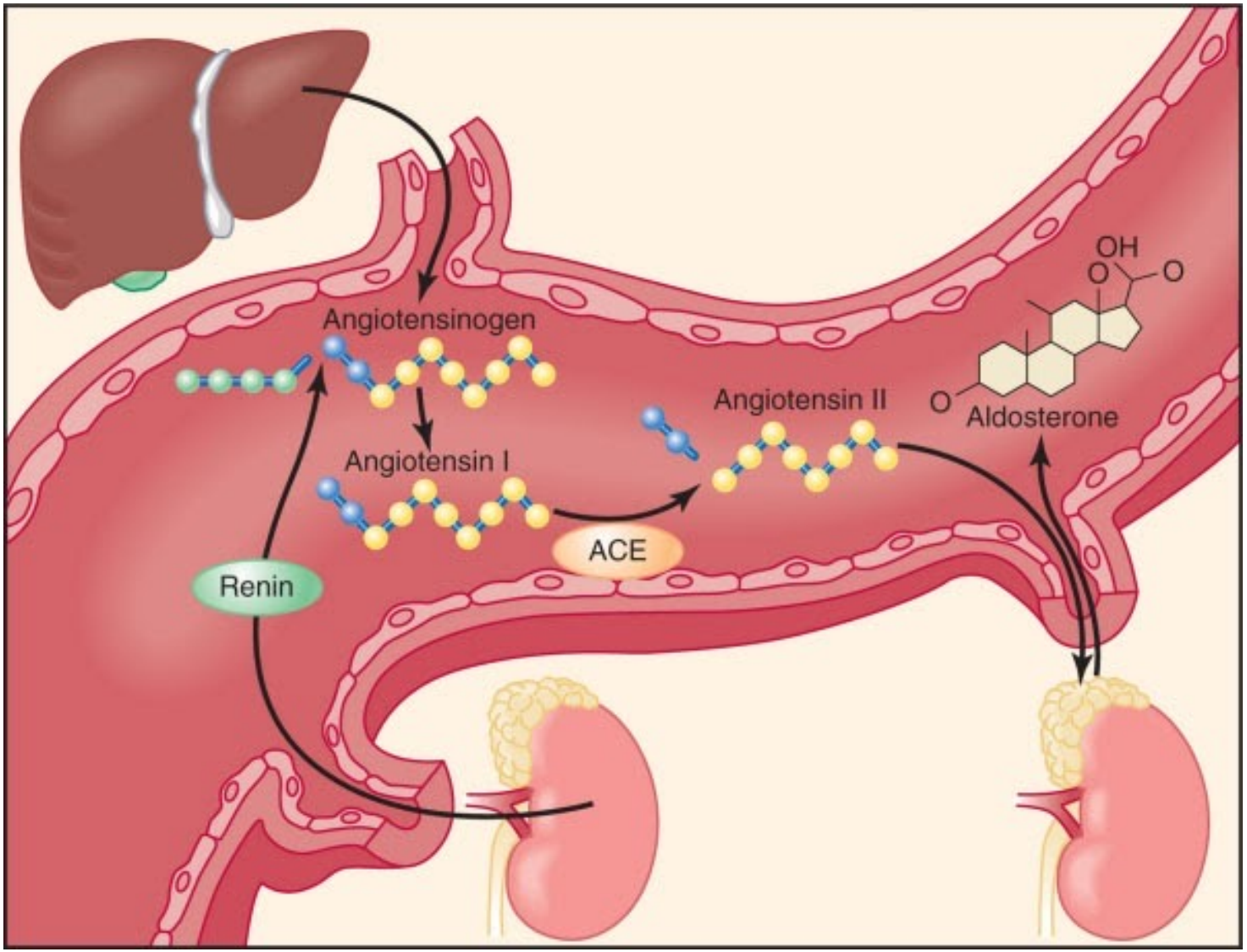
Kidneys and blood pressure

When blood volume (and, therefore, blood pressure) falls too low for filtration to occur, the juxtaglomerular apparatus can respond by secreting **renin.**

Renin

Renin - an enzyme that leads to the secretion of aldosterone by the adrenal glands.




Angiotensinogen
Angiotensin I
Angiotensin II
ACE
Renin
OH
O
O
O
Aldosterone

Renin-angiotensin-aldosterone system (RAAS)