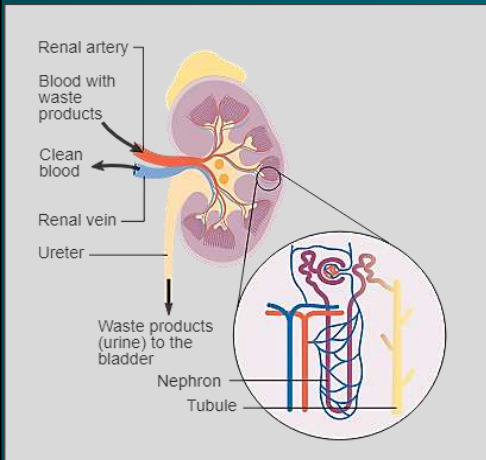




Human Excretory System (Part 1)



Human Anatomy & Physiology

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Human Excretory System

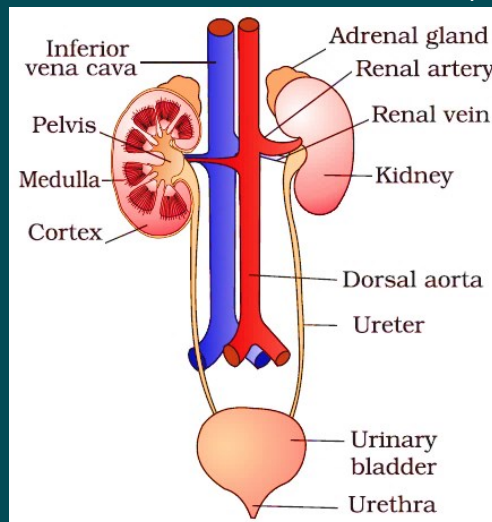


- ❏ The human excretory system is a vital biological system that removes/excretes excess and waste products/metabolite from the body to maintain homeostasis (electrolyte/fluid)
- ❏ The major excretion occurs via urine, so also known as urinary system
- ❏ However, waste/metabolites can also excrete via
 - ❏ Faces (unabsorbed fractions)
 - ❏ Exhaled air (Lungs)- alcohol
 - ❏ Saliva
 - ❏ Milks

Human Excretory System



- ❏ The major organs involved in the excretory/urinary system include
 - ❏ 2 kidneys,
 - ❏ 2 ureters,
 - ❏ 1 bladder
 - ❏ 1 urethra.



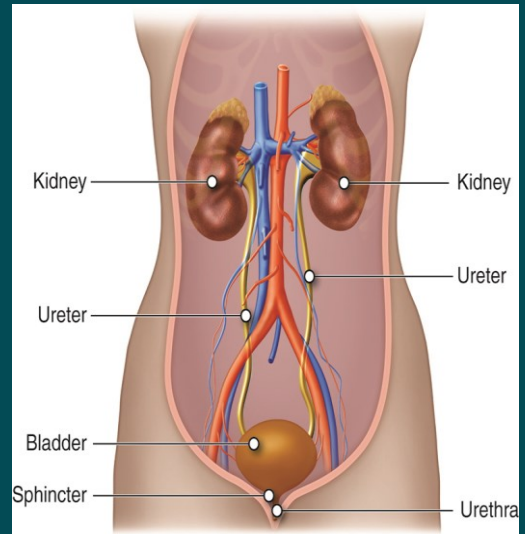
Source: <https://classnotes123.com/excretory-system-diagram-class-10/>

Human Excretory System



1. Kidneys:

- 📌 It is the main organs. We typically have two kidneys,
- 📌 They lie on the posterior abdominal wall, one on each side of the vertebral column, behind the peritoneum and below the diaphragm
- 📌 12th thoracic vertebra to the 3rd lumbar
- 📌 The right kidney is usually slightly lower than the left, probably because of the considerable space occupied by the liver.



<https://pressbooks.ccconline.org/bio106/chapter/urinary-structures-and-functions/>

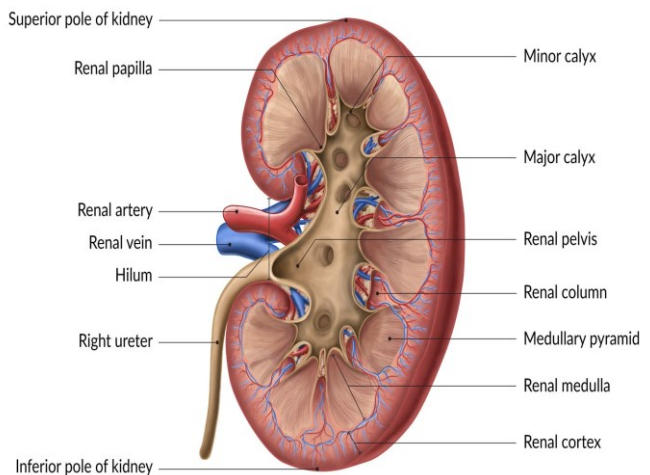
Human Excretory System



1. Kidneys:

- 📌 Kidneys are bean-shaped organs, about 11 cm long, 6 cm wide, 3 cm thick and weigh 150 g
- 📌 The kidneys filter the blood to remove waste products, excess water, and other substances.
- 📌 They also play a vital role in regulating electrolyte balance and acid-base balance. T
- 📌 The functional units of the kidneys are called nephrons (1-2 Million), which are responsible for the filtration and reabsorption of various substances

Source: <https://www.amboss.com/us/knowledge/Kidneys>

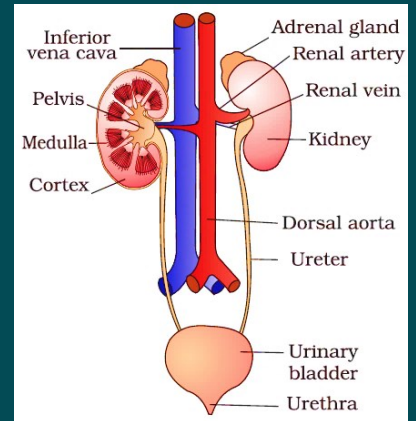


Human Excretory System



2. Ureters:

- ❏ The ureters are thin, muscular tubes that connect each kidney to the bladder.
- ❏ They transport urine from the kidneys to the bladder using peristaltic contractions.
- ❏ The ureters prevent the backflow of urine from the bladder to the kidneys through the presence of one-way valves.

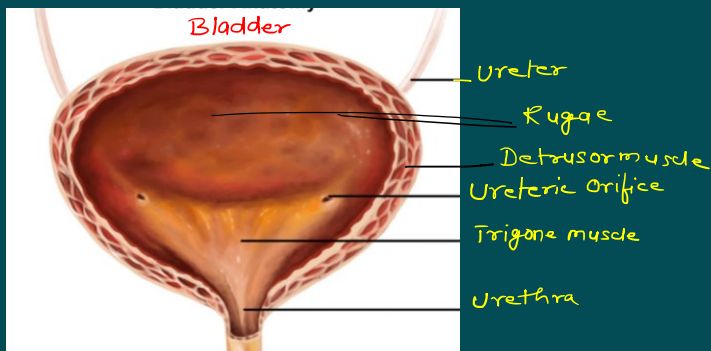


Human Excretory System



3. Bladder:

- ❏ The bladder is a hollow, muscular organ located in the lower abdomen.
- ❏ It acts as a temporary storage reservoir for urine.
- ❏ The bladder expands as it fills with urine, and once it reaches a certain capacity, it sends signals to the brain to initiate the sensation of needing to urinate

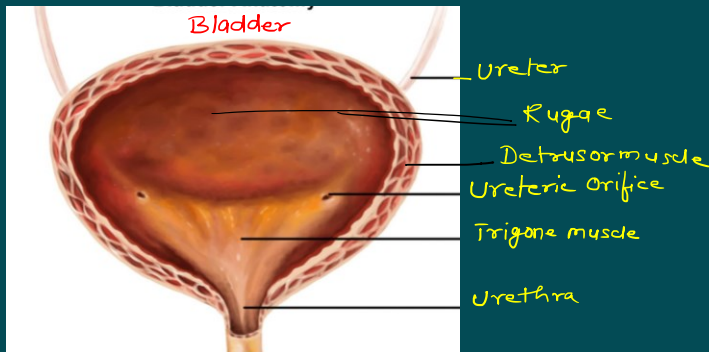


Human Excretory System



4. Urethra:

- ❑ The urethra is a tube that connects the bladder to the external opening of the body. In males, it serves the dual function of transporting both urine and semen.
- ❑ In females, it is shorter and only carries urine. The urethral sphincter muscles help control the flow of urine and prevent leakage



Human Excretory System



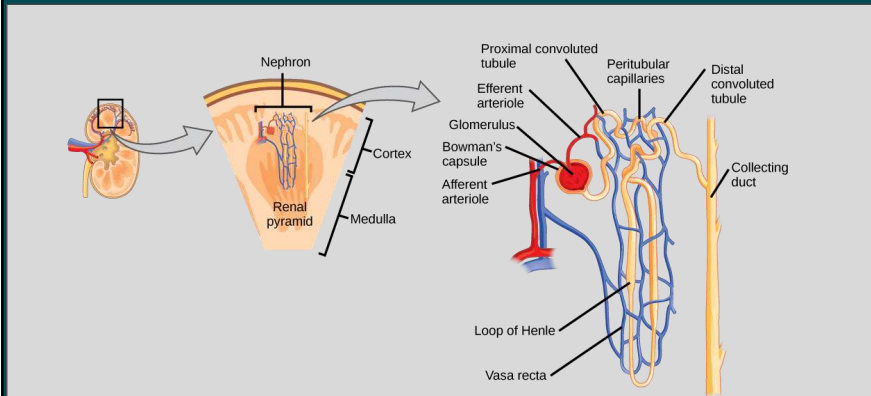
Basic Function of Urinary System:

- ❑ Excretion: Waste metabolite, urea, creatinine, excess salts, and water
- ❑ The kidneys filter the blood, reabsorb necessary substances such as glucose and amino acids, and concentrate waste products into urine.
- ❑ plays a crucial role in maintaining fluid and electrolyte balance, regulating blood pressure, and eliminating waste products from the body, thus helping to maintain overall health and homeostasis



Human Excretory System (Part 2)

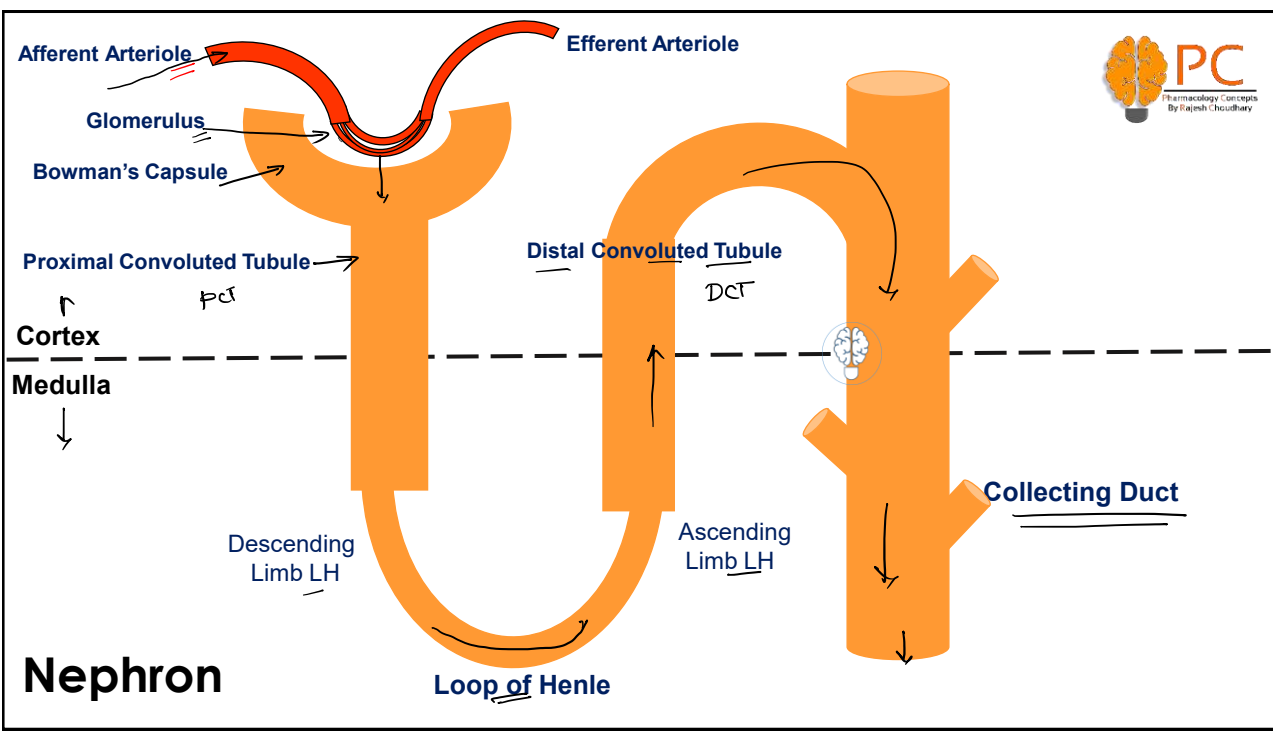
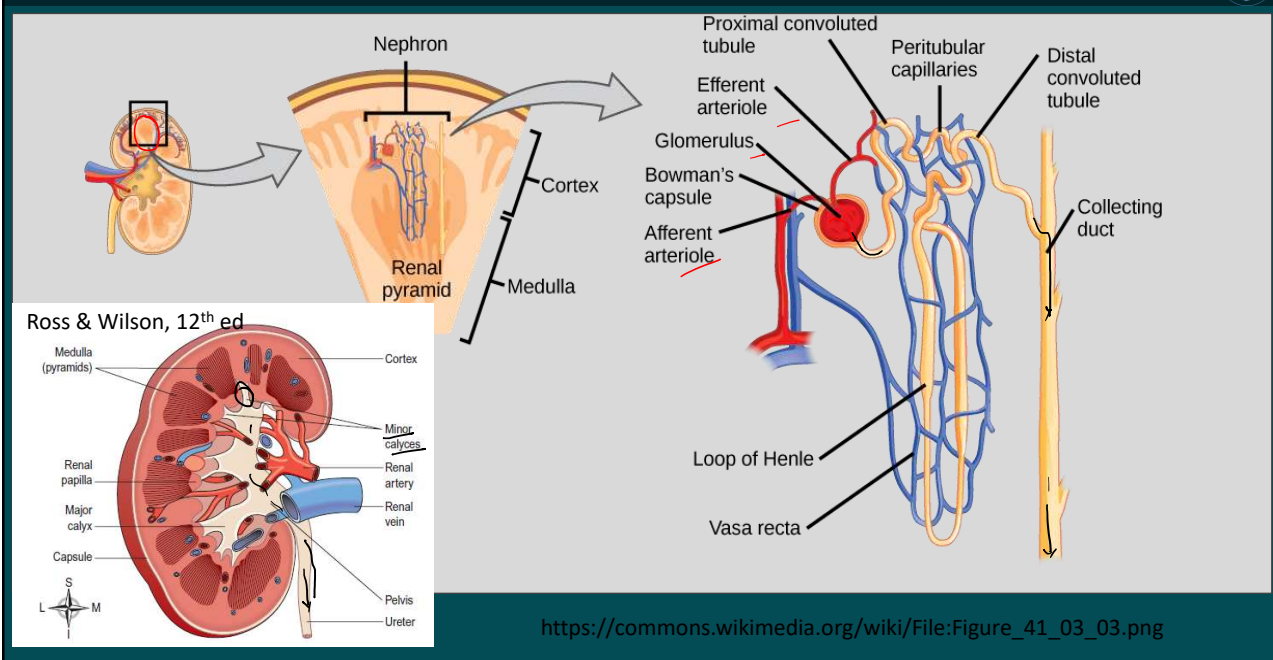
Nephron & Urine Formation



Human Anatomy & Physiology

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Human Excretory System

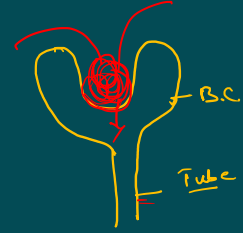


Human Excretory System



Nephron:

- ❏ Structural and Functional unit of Kidneys ✓
- ❏ The closed end is indented to form the cup-shaped glomerular capsule (Bowman's capsule), which almost completely encloses a network of tiny arterial capillaries, which known to glomerulus, single layer of flattened epithelial cells, which is more permeable than other tubules (single layer of simple squamous epithelium). ✗
- ❏ About 3 cm long of tube, consisting of-
 - ❏ the **proximal convoluted tubule (PCT)** ✓
 - ❏ the medullary loop (loop of Henle, **LH**) ✓
 - ❏ the distal convoluted tubule (**DCT**), leading into a collecting duct (**CD**).

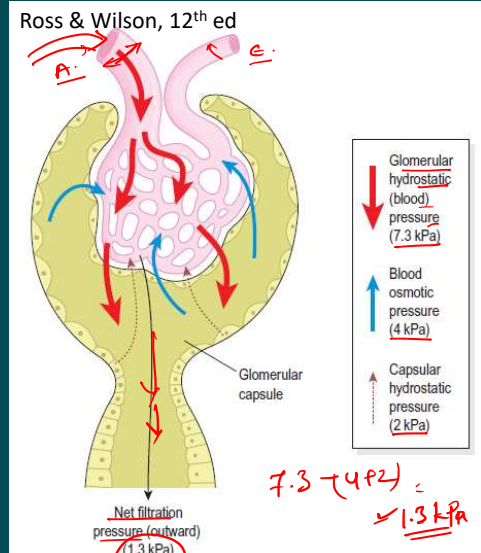


Human Excretory System



Nephron:

- ❏ Kidneys received about 20% of cardiac output
Blood enter through afferent arterioles to the capillary network (Glomerulus),
- ❏ Between these capillary loops are connective tissue phagocytic mesangial cells, which are part of the monocyte-macrophage defense system ✗
- ❏ The **afferent arteriole** has a larger diameter than the **efferent arteriole**, which increases pressure inside the glomerulus and drives filtration across the glomerular capillary walls

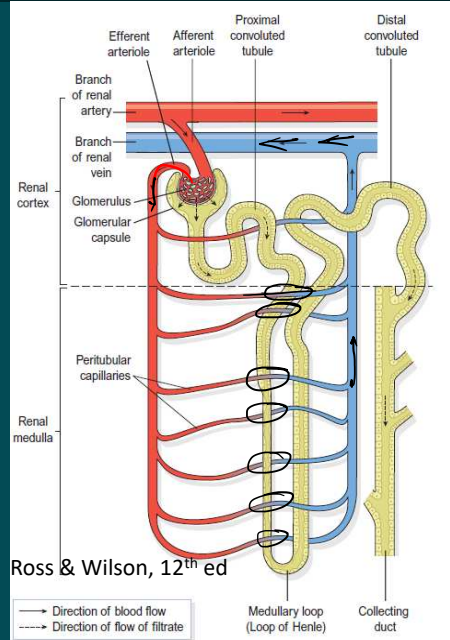


Human Excretory System



Nephron:

- ☛ The **efferent arteriole** divides into a second peritubular (meaning 'around tubules') capillary network, which wraps around the remainder of the tubule, allowing exchange between the fluid in the tubule and the bloodstream
- ☛ This maintains the local supply of oxygen and nutrients and removes waste products



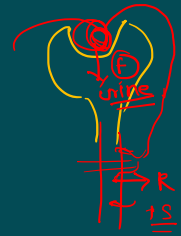
Human Excretory System



- ☛ The composition of urine reflects exchange of substances between the nephron and the blood in the renal capillaries.
- ☛ Waste products of protein metabolism are excreted, water and electrolyte levels are controlled and pH (acid-base balance) is maintained by excretion of hydrogen ions.
- ☛ There are three processes involved in the **formation of urine**:

- ☛ Glomerular Filtration ✓
- ☛ Tubular Reabsorption ✓
- ☛ Tubular Secretion

$$\text{Urine output} = (\text{GF} + \text{TS}) - \text{TR}$$



Human Excretory System



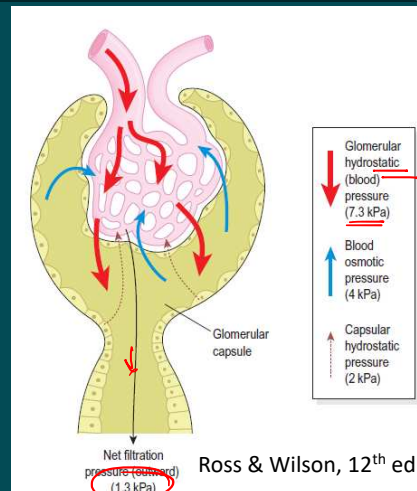
1. Filtration:

- This takes place through the semipermeable walls of the glomerulus and glomerular capsule
- Water and small molecules (ions, glucose, urea, etc) are filtered through the filtration pressure (1.3kPa or 10 mmHg).

Glomerular Hydrostatic pressure- (blood osmotic pressure + capillary hydrostatic pressure)

$$\checkmark 7.3 - (4 + 2) = 1.3 \text{ kPa}$$

$$\checkmark 55 - (30 + 15) = 10 \text{ mmHg}$$



Human Excretory System



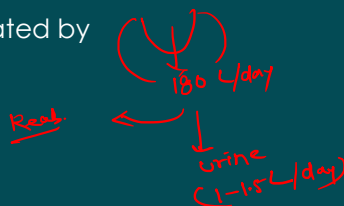
1. Filtration:

- Large molecules remain unfiltered
- The volume of filtrate formed by both kidneys each minute is called the glomerular filtration rate (GFR)
- GFR = 120 ml/min (180 liter/day by both kidneys)
- Nearly all of the filtrate is later reabsorbed from the kidney tubules (by tubular reabsorption) with less than i.e. 1-1.5 litres excreted as urine.
- The renal blood flow and GFR is regulated by AUTOREGULATION process

Box 13.1 Constituents of glomerular filtrate and glomerular capillaries

Blood constituents in glomerular filtrate	Blood constituents remaining in glomerular capillaries
Water	Leukocytes
Mineral salts	Erythrocytes
Amino acids	Platelets
Ketoacids	✓ Plasma proteins
Glucose	✓ Some drugs (large molecules)
Some hormones	✓ <u>Protein binding drugs</u> (unfiltered)
Creatinine	
Urea	
Uric acid	
Some drugs (small molecules)	

Ross & Wilson, 12th ed



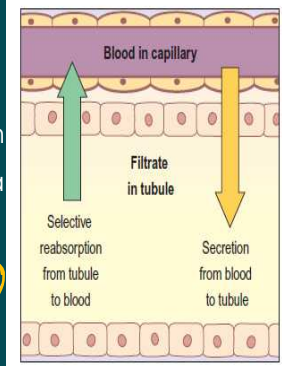
Human Excretory System



2. Selective Reabsorption:



- Large molecules remain unfiltered
- Most of the molecules are reabsorb back (passively and actively) in the PCT, whose walls are lined with microvilli to increase surface area for absorption.
- Many substances are reabsorbed here, including some water, electrolytes and organic nutrients such as glucose.
- Some reabsorption is passive, but some substances, e.g. glucose, are actively transported
- 60-70% reaches to Medullary loop and Much of this, especially water, sodium and chloride, is reabsorbed in the loop,
- 15-20% reaches to DCT
- And most electrolyte reabsorb in DCT via active transport system



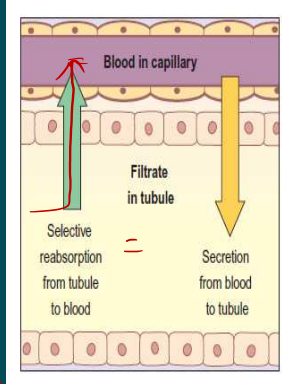
Ross & Wilson, 12th ed

Human Excretory System



2. Selective Reabsorption:

- And most electrolyte (Na^+, K^+, Cl^-) reabsorb in DCT, and reaches dilute urine to collecting duct.
- In collective duct most of the water are reabsorbed
- Some constituents of glomerular filtrate (e.g. glucose, amino acids) do not normally appear in urine because they are completely reabsorbed unless blood levels are excessive (glucose $> 160mg/dl$)
- Reabsorption of nitrogenous waste products, such as urea, uric acid and creatinine is very limited



Ross & Wilson, 12th ed

g₁₄ - 80-120-140 mg/dl
g₁₄ > 160 mg/dl

Reab
 ✓ PCT - water, ions, Glucose
 ✓ LH - H⁺ ions
 ✓ DCT = ions
 ✓ CD = water and

Human Excretory System



Hormones that affect reabsorption

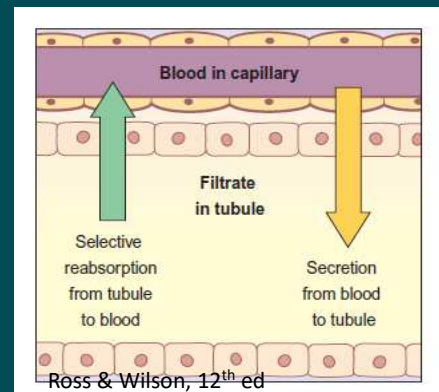
- ▼ **Aldosterone** (secrete by adrenal cortex)- increase the reabsorption of Sodium and water
- ▼ **Anti-diuretic hormone** (secrete by posterior pituitary hormone)- increase the permeability for water in DCT and Collecting duct
- ▼ **Parathyroid hormone-** (secrete by parathyroid gland)- regulates the reabsorption of calcium and phosphate from the distal collecting tubules. Parathyroid hormone increases the blood calcium level and calcitonin lowers it.
- ▼ **Atrial natriuretic peptide** (ANP). This hormone is secreted by the atria of the heart in response to stretching of the atrial wall when blood volume is increased. decreases reabsorption of sodium and water from the proximal convoluted tubules and collecting ducts

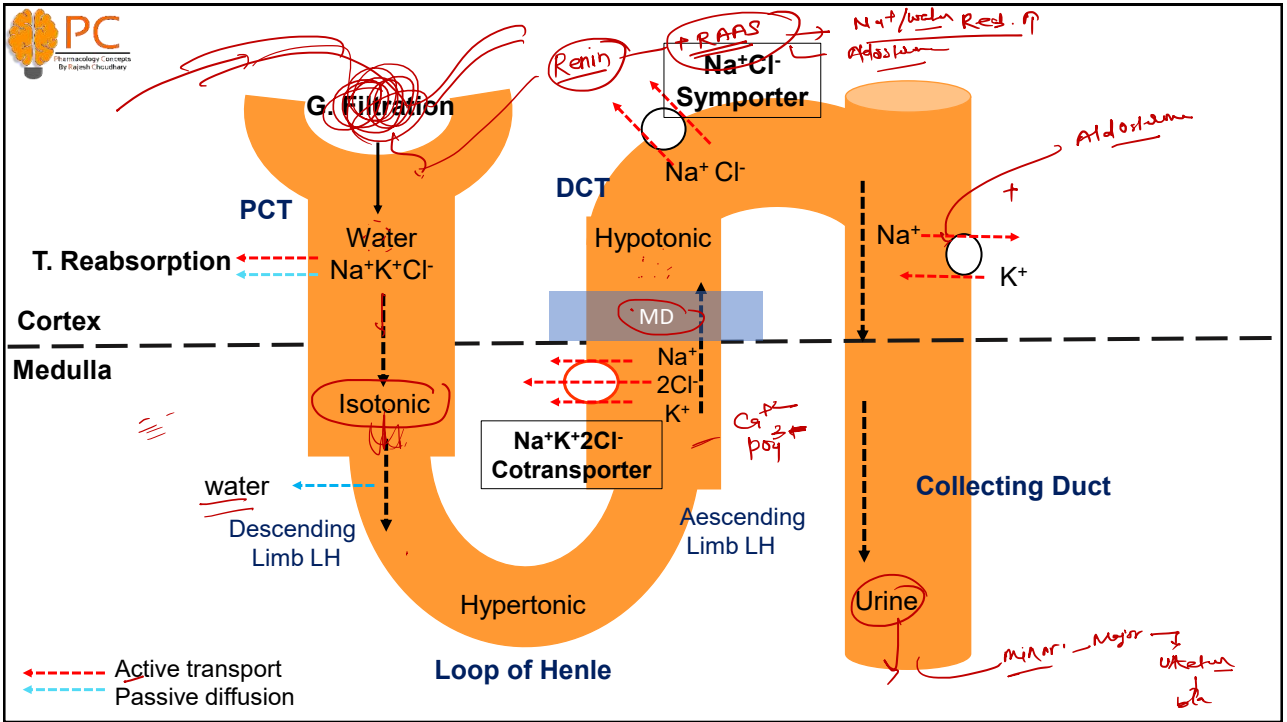
Human Excretory System



3. Tubular Secretion:

- ▼ Many drugs including penicillin and aspirin, may not be entirely filtered out of the blood because of the short time.
- ▼ it remains in the glomerulus. Such substances are cleared by secretion from the peritubular capillaries into the filtrate within the convoluted tubules.
- ▼ Tubular secretion of hydrogen ions (H⁺) is important in maintaining normal blood pH





Human Excretory System

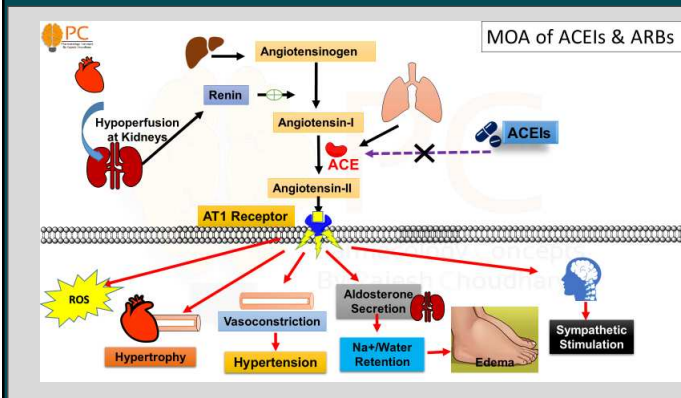
Urine:

- Many drugs including penicillin and aspirin, may not be entirely filtered out of the blood because of the short time.
- Urine is clear and amber in colour due to the presence of urobilin, a bile pigment altered in the intestine, reabsorbed then excreted by the kidneys.
- The specific gravity is between 1020 and 1030, and the pH is around 6 (normal range 4.5–8).
- A healthy adult passes from 1000 to 1500 mL per day

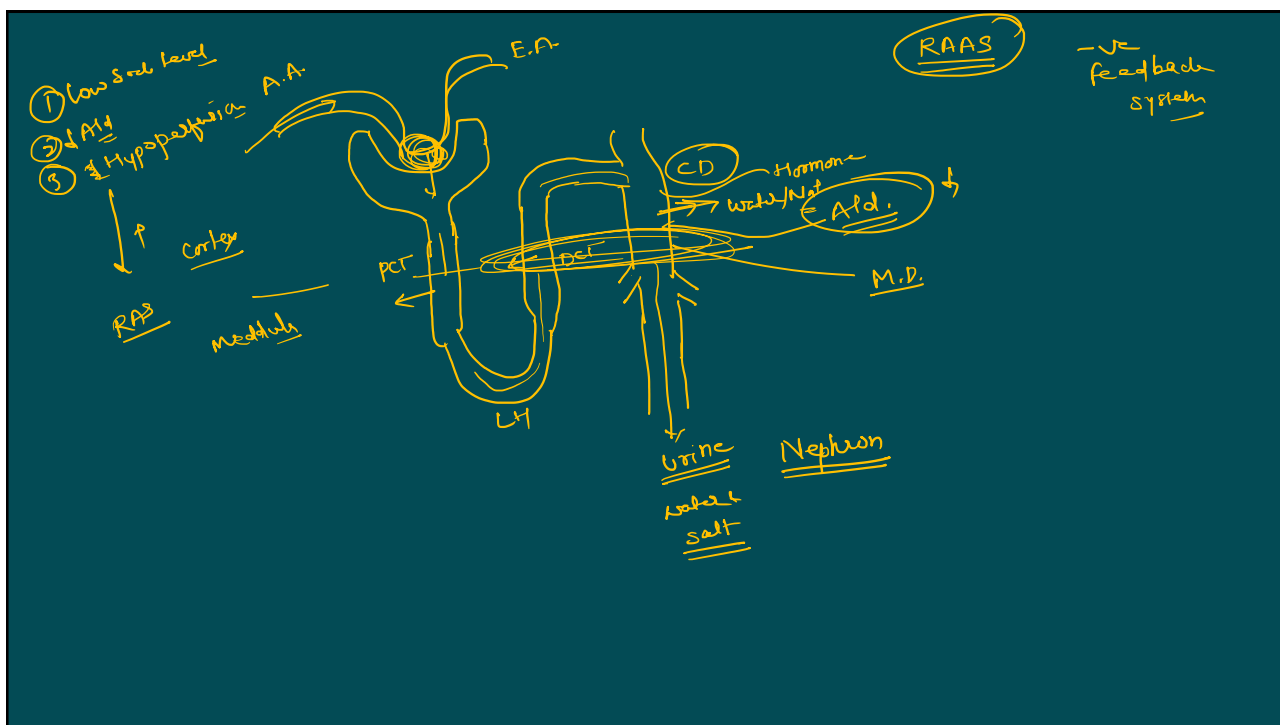
Water	96%		
Urea	2%		
Uric acid	}	Chlorides	} 2%
Creatinine		Phosphates	
Ammonia	} 2%	Sulphates	
Sodium		Oxalates	
Potassium			
		Ross & Wilson, 12 th ed	

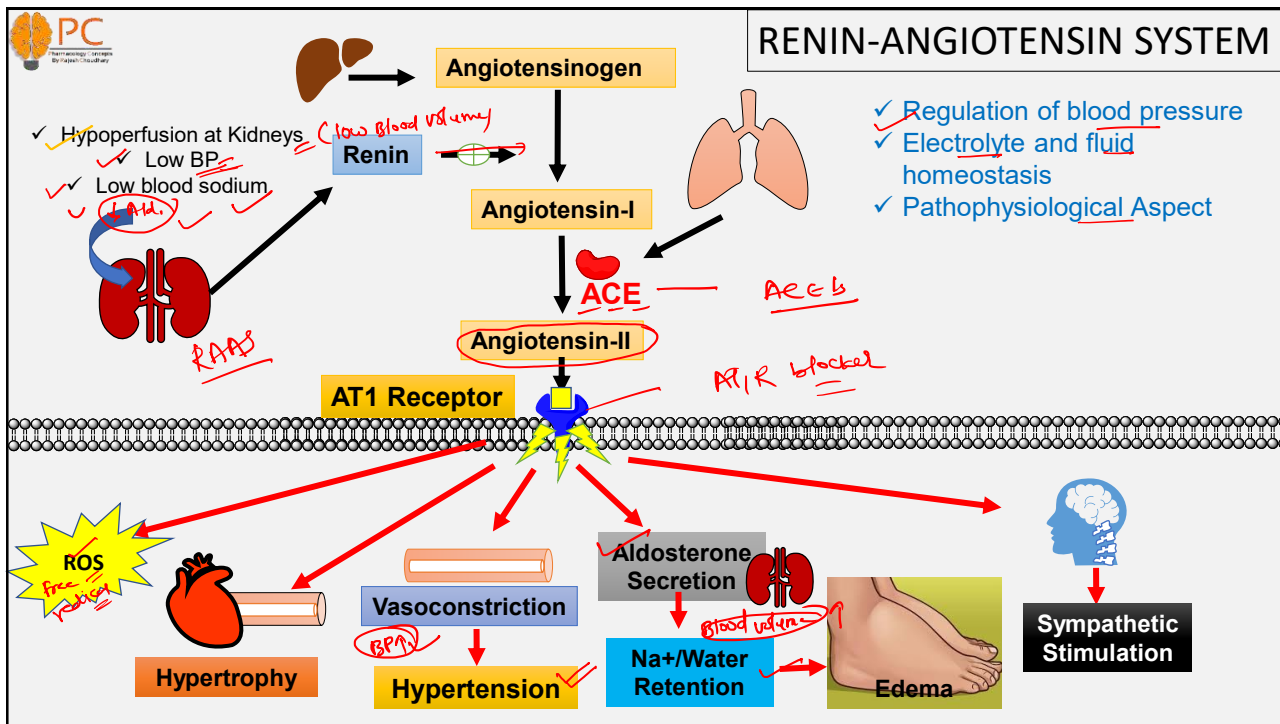


Human Excretory System (Part 3) Role of RAS in Kidney



Human Anatomy & Physiology





Human Excretory System (Part 4)

Kidney's Role in Acid-Base Balance Balance Blood pH

URINE BLOOD

HCO_3^- (Bicarbonate) →

← H^+

Human Anatomy & Physiology

Kidney's Role in Acid-Base Balance

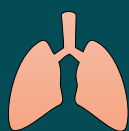


Acid-Base Regulators:

1. Buffers

2. Lungs

3. Kidneys



Blood
pH = 7.4

Henderson-Hasselbach Eq. for pH

$$pH = pK + \log [A^- / HA]$$

$\uparrow H^+ \rightarrow \downarrow pH \rightarrow$ Acidosis

$\downarrow H^+ \rightarrow \uparrow pH \rightarrow$ Alkalosis

Kidney's Role in Acid-Base Balance



Henderson-Hasselbach Eq. for pH

$$pH = pK + \log [A^- / HA]$$

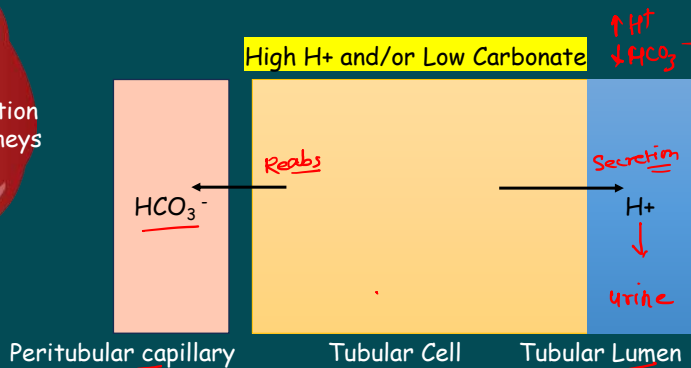
Imp Strong Buffer pair:

$$HCO_3^- / CO_2, \quad pK = 6.1$$

$$pH = 6.1 + \log [HCO_3^- / 0.03 \times Pa CO_2]$$

Role of Kidneys: Slow but powerful

1. They reabsorb bicarbonate from urine.
2. They excrete hydrogen ions into urine.



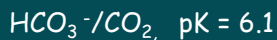
Kidney's Role in Acid-Base Balance



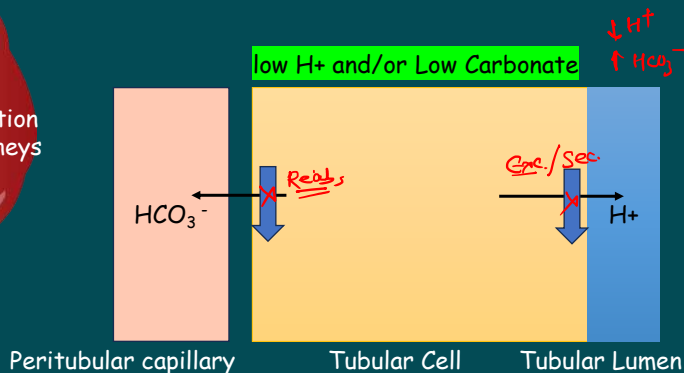
Henderson-Hasselbach Eq. for pH

$$pH = pK + \log [A^- / HA]$$

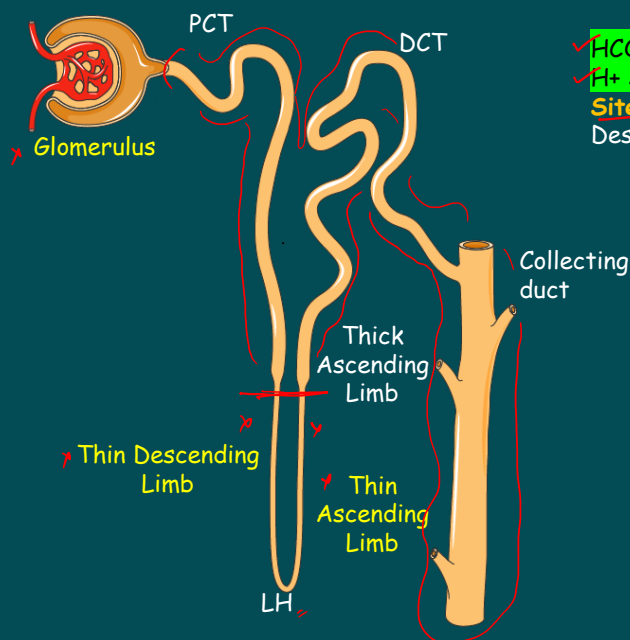
Imp Strong Buffer pair:



$$pH = 6.1 + \log [HCO_3^- / 0.03 \times Pa CO_2]$$



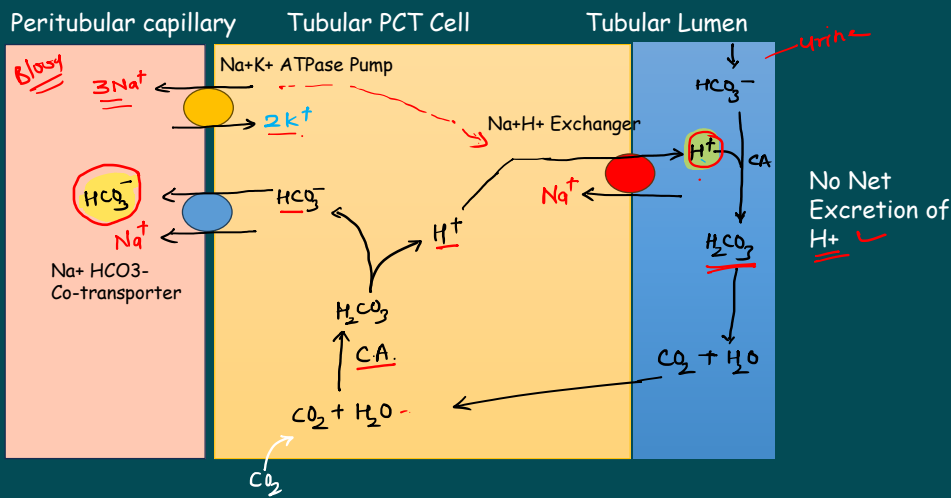
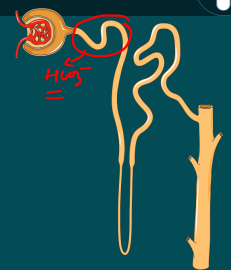
Human Excretory System



- ✓ HCO_3^- Reabsorption
- ✓ H^+ Secretion
- Sites:** All tubules except Thin Descending/Ascending limb LH

Kidney's Role in Acid-Base Balance

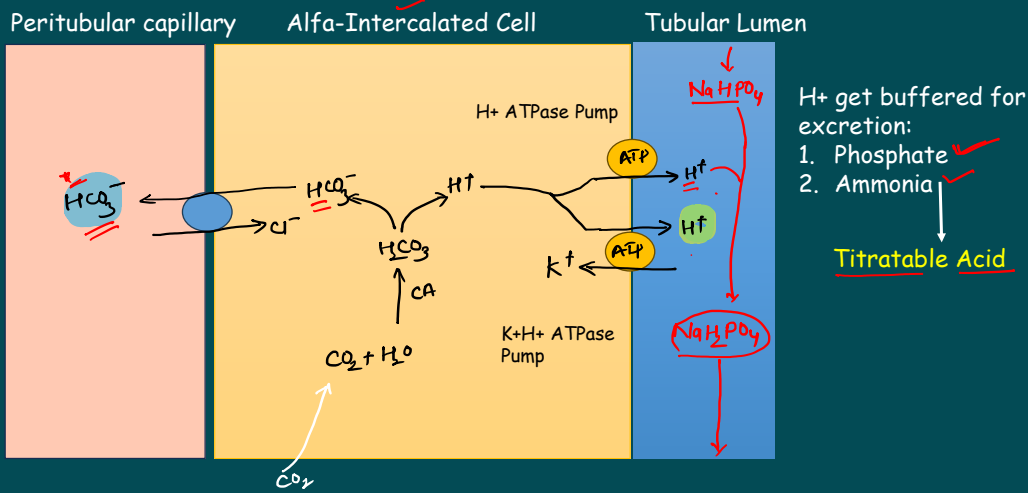
HCO₃⁻ Reabsorption: 80% in early PCT



Kidney's Role in Acid-Base Balance

H⁺ Secretion: most in DCT & CT

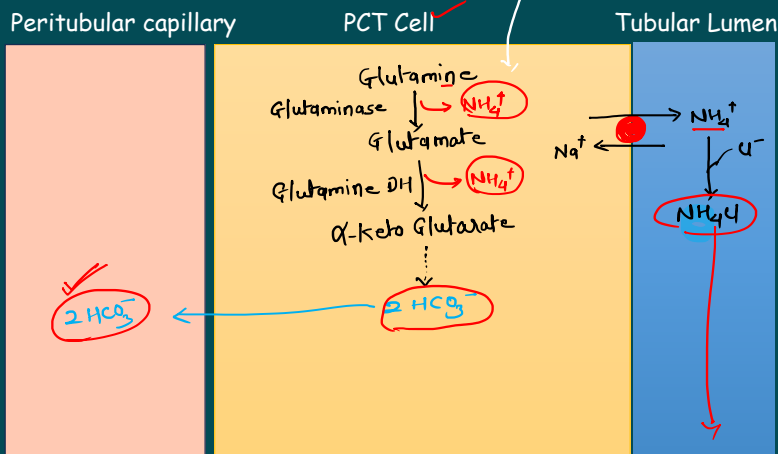
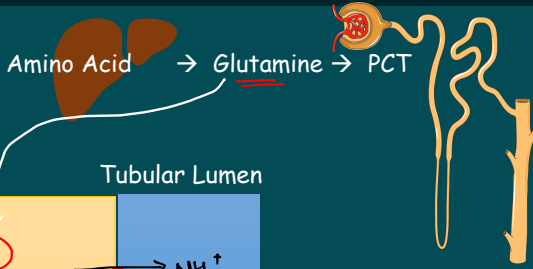
urine max ↓ pH = 4.4



Kidney's Role in Acid-Base Balance



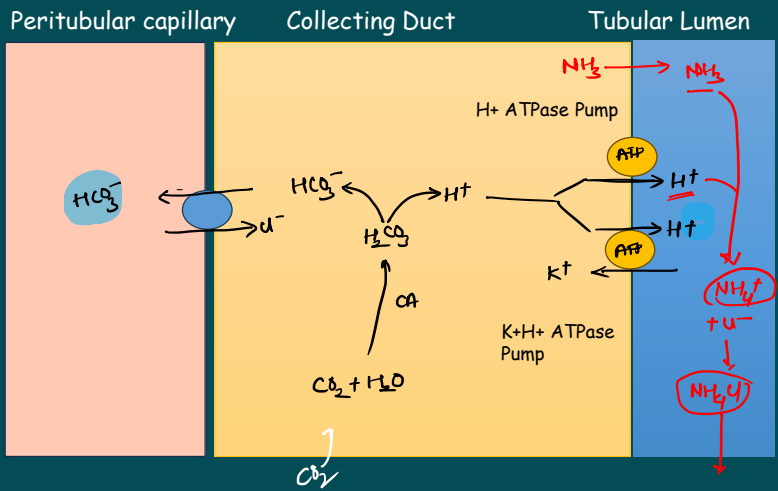
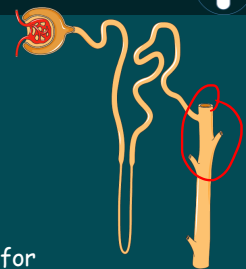
Ammonia Buffer



Kidney's Role in Acid-Base Balance



Ammonia Buffer



H^+ get buffered for excretion:

1. Phosphate
2. Ammonia

↓

Titrateable Acid

Kidney's Role in Acid-Base Balance



Factors:

$$pH = pK_a + \log \left[\frac{HCO_3^-}{0.03 \times P_a CO_2} \right]$$



Resp. Acidosis

↑ Pa CO₂ ↓ pH

$$\downarrow pH = pK + \log \left[\frac{HCO_3^-}{0.03 \times P_a CO_2 \uparrow} \right]$$

↑ HCO₃⁻ Reabsorption
 ↓ H⁺ Secretion
 (Kidneys)

Resp. Alkalosis:

↓ Pa CO₂ ↑ pH

$$\uparrow pH = pK + \log \left[\frac{HCO_3^-}{0.03 \times P_a CO_2 \downarrow} \right]$$

↓ HCO₃⁻ Reabsorption
 ↓ H⁺ Secretion

Metabolic Acidosis

↓ HCO₃⁻ ↑ HCO₃⁻ Reabsorption
 ↑ H⁺ ↑ H⁺ Secretion

Metabolic Alkalosis

↑ HCO₃⁻ ↓ HCO₃⁻ Reabsorption
 ↓ H⁺ ↓ H⁺ Secretion



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