Physiology of Excretion

Functional Excretion System

- This is a set of organs involved in the removal of substances from the body and the mechanisms of neurohumoral regulation of the activity of these organs.

The Excretory System Includes:

- Lungs,
- Digestive tract
- Liver,
- Leather,
- Mammary gland,
- Peritoneum,
- The kidneys.

The kidneys are of primary importance.

Kidney Functions

1. Excretory Functions
2. Non-excretory Functions

Kidney Excretory Functions

- **Excretory** (excretion of substances from the body).
- **Homeostatic** (participation in maintaining the water-salt balance, acid-base balance, fluid volume in the body).

Kidney Non-excretory Functions

- **Incretory** (synthesis of biologically active substances - renin, erythropoietin, erythropoiesis inhibitor).
- **Metabolic** (metabolic processes occur in the kidneys).

Nephron

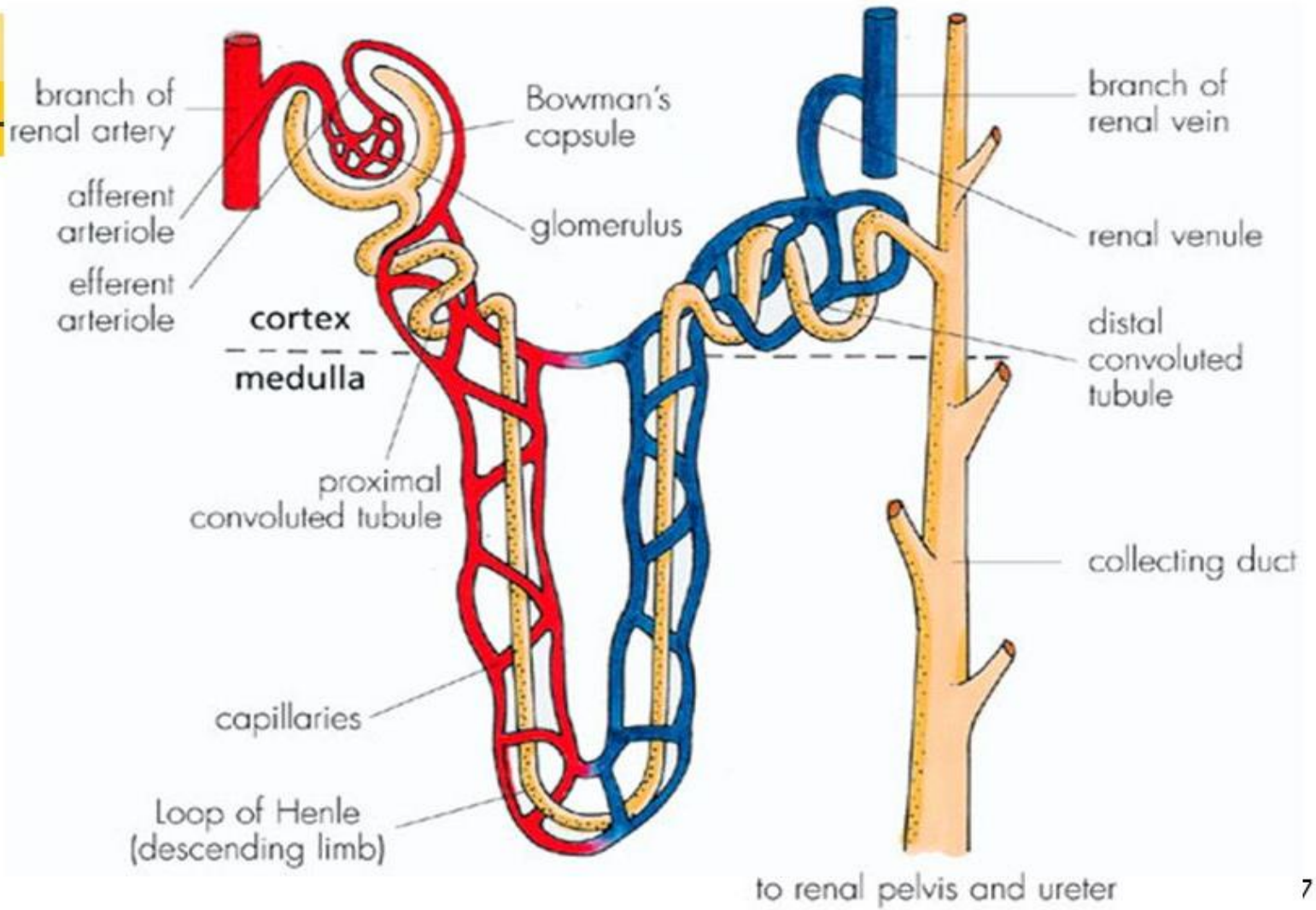
- It is a structurally functional unit of the kidney.
- Nephrons are cortical and juxtamedullary.
- The main processes that ensure the formation of urine occur in cortical nephrons.

Nephron Structure

- **The renal body** consists of a capillary glomerulus and a Shumlyansky-Bowman capsule.
- **The proximal segment** consists of a proximal convoluted tubule and a thick descending tubule of the Henle loop.
- **Thin part of the loop of Henle**.
- **The distal segment** consists of a thick ascending tubule of the loop of Henle and a distal convoluted tubule.

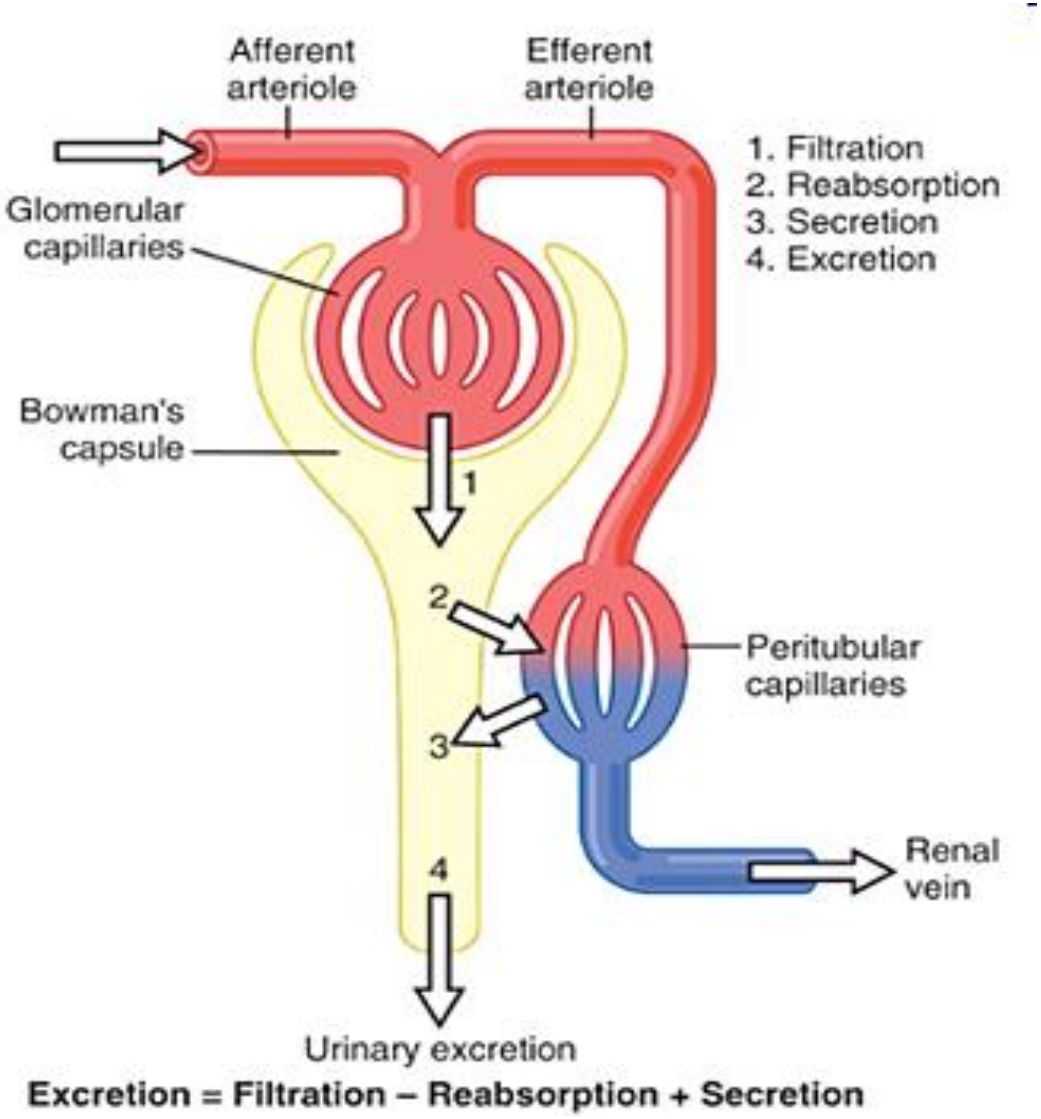
Distal convoluted tubules of nephrons flow into the collecting ducts.

The structure of a nephron



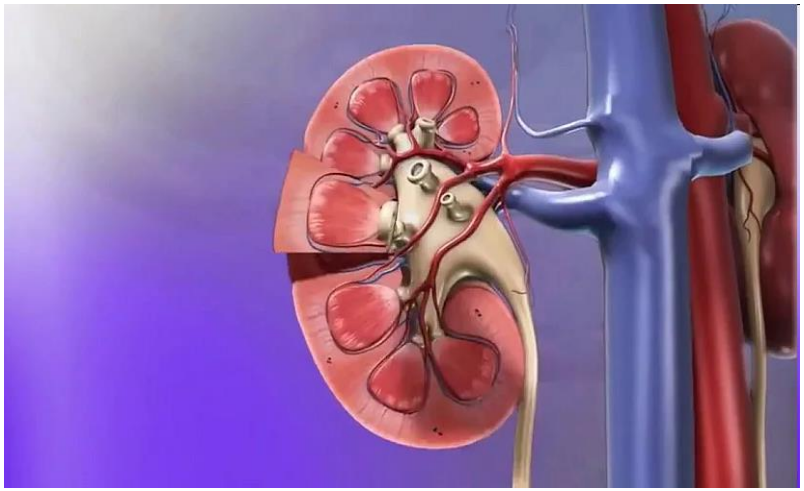
The Processes of Urine Formation

- Filtration
- Reabsorption
- Secretion



Features of Blood Circulation in the Kidneys

1. 25% of the minute volume of blood flow passes through the kidneys.



The renal artery is short, wide, departs from the abdominal aorta at a right angle. Therefore, it has high hydrostatic blood pressure.

Features of Blood Circulation in the Kidneys

2. 90% of the blood flows through the cortex and through the medulla 10%.

3. Renal blood flow is relatively independent of systemic blood pressure.

Features of Blood Circulation in the Kidneys

4. Two capillary networks are in the nephron.

- The primary capillary network
- The secondary capillary network

The Primary Capillary Network

- It is the glomerulus.
- It is formed from the afferent arteriole.
- The diameter of the afferent arteriole is larger than the diameter of the efferent arteriole.
- Therefore, the glomerulus has high hydrostatic pressure. This is necessary for filtration.

The Secondary Capillary Network

- It is formed from the efferent arteriole.
- The capillaries of this capillary network surround the tubules. This is necessary for reabsorption.

5. Features of Blood Circulation in a Juxtamedullary Nephrons

In juxtamedullary nephrons:

- The diameter of the afferent and efferent arterioles is the same.
- There is no secondary capillary network.
- Therefore, the processes of urine formation are practically absent.

Filtration (Ultrafiltration)

- It is the process of primary urine formation.
- Filtration occurs in the body of the nephron.
- The components of the blood plasma pass from the capillaries of the glomerulus into the cavity of the Shumlyansky-Bowman capsule.
- Blood cells and macromolecular compounds (globulins) do not pass through the renal filter.
- 180-200 liters of primary urine are formed per day.

Renal Filter Layers

- Endothelium of the capillary glomerulus
- Basement membrane
- Podocytes of the Shumlyansky-Bowman capsule

Effective Filtration Pressure (EFP)

- This is the force due to which filtering occurs.

EFP = hydrostatic blood pressure – (oncotic blood pressure + primary urine hydrostatic pressure)

EFP = 15 – 20 mmHg.

Glomerular Filtration Assessment Method

- This is the **clearance method**.
- The **glomerular filtration rate** is determined.
- **Indicator substance** used. This can be:

1. Inulin (it must be injected into the blood throughout the study),
2. Creatinine (formed in the body by the breakdown of proteins in the muscles).

Requirements for the Indicator Substances

1. It should not be toxic.
2. It should not take part in chemical reactions in the body.
3. It must pass through the renal filter.
4. It should not be reabsorbed in the renal tubules.
5. It should not be secreted in the renal tubules.

Glomerular Filtration Rate

$$GFR = \frac{Vm \cdot Cm}{Cpl}, \text{ where}$$

GFR - glomerular filtration rate (мл/мин),

Vm – final urine formation rate (final urine volume in 1 minute),

Cm – the concentration of the indicator substance in the final urine,

Cpl – the concentration of the indicator substance in the blood plasma.

Reabsorption

- This is the process of the reverse transition of substances from the tubules of the nephron to the blood.
- Reabsorption continues in collecting ducts.
- 80% of the ultrafiltrate is returned to the plasma.
- The result is secondary and final urine.
- Daily diuresis is 1.5 - 2 liters.

Reabsorption Mechanisms

- Primarily active transport
- Secondarily active transport
- Passive transport
- Pinocytosis

Active Transport

- **Primarily Active Transport**

This is transport using carrier proteins involving ATP.

So, for example, Na + ions are transferred.

- **Secondarily Active Transport**

This is transport using carrier proteins but without ATP.

So glucose and amino acids are transferred. The carrier protein is activated by sodium ions.

Passive Transport

- This is a gradient transport.

For example,

- Cl– ions are transferred after Na + along the electrochemical gradient.
- Water is reabsorbed by an osmotic gradient.

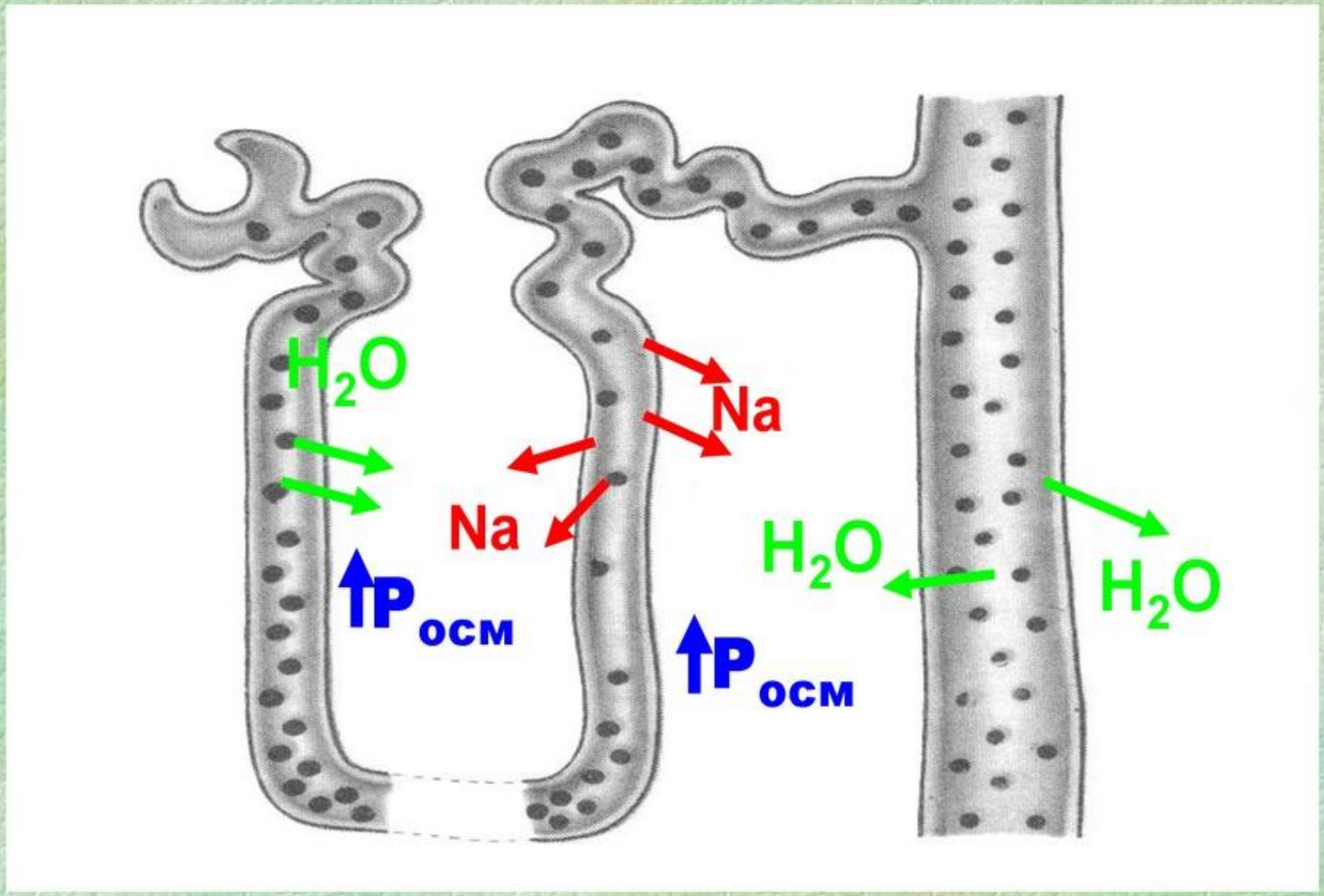
Pinocytosis

- This is the transfer of macromolecular substances through the cells of the tubule epithelium.
- This occurs due to endocytosis and exocytosis.
- So albumins are reabsorbed. They should not be in the final urine.

Rotary Countercurrent Multiplier Mechanism (Rotary Multiplier)

- This is the mechanism by which ions and a large amount of water are reabsorbed.
- The rotary multiplier functions in the Henle loop.

Механизм поворотно-противоточной системы



Rotary Multiplier

- Reabsorption of sodium and chlorine ions occurs in the ascending part of the Henle loop.
- Sodium is reabsorbed actively, chlorine moves after sodium along the electrochemical gradient.
- The osmotic pressure in the interstitium increases.
- Water is reabsorbed according to the osmotic gradient in the descending section of the Henle loop and in collecting ducts.
- As a result, the amount of urine is significantly reduced.
- There is a process of urine concentration.

Types of Reabsorption

- **Obligatory reabsorption** occurs in the proximal segment of the nephron. This is a mandatory reabsorption. It does not depend on regulatory factors.
- **Optional reabsorption** occurs in the distal nephron segment and in the collecting duct. Various factors can regulate it.

Threshold Substances

- Glucose and amino acids are threshold substances.
- **The excretion threshold** is the minimum concentration of a substance in the blood at which it cannot be completely reabsorbed and appears in the urine. This is because there are not enough carrier molecules.
- The excretion threshold for glucose is 9-10mmol/l.

Assessment of Tubular Reabsorption

Conditions for the Appearance of Glucose in the Final Urine:

- The concentration of glucose in the blood exceeds the excretion threshold.
- Reabsorption is disturbed (tubule epithelium is damaged). In this case, the concentration of glucose in the blood does not exceed the excretion threshold.

Tubular Secretion

- This is the elimination of substances from epithelial cells into the lumen of the tubules of the nephron.
- These substances can enter the tubular epithelial cells from the blood or form in these cells.
- Ions of potassium, hydrogen, ammonium, organic acids and bases, penicillin and some other substances are secreted by tubular secretion.

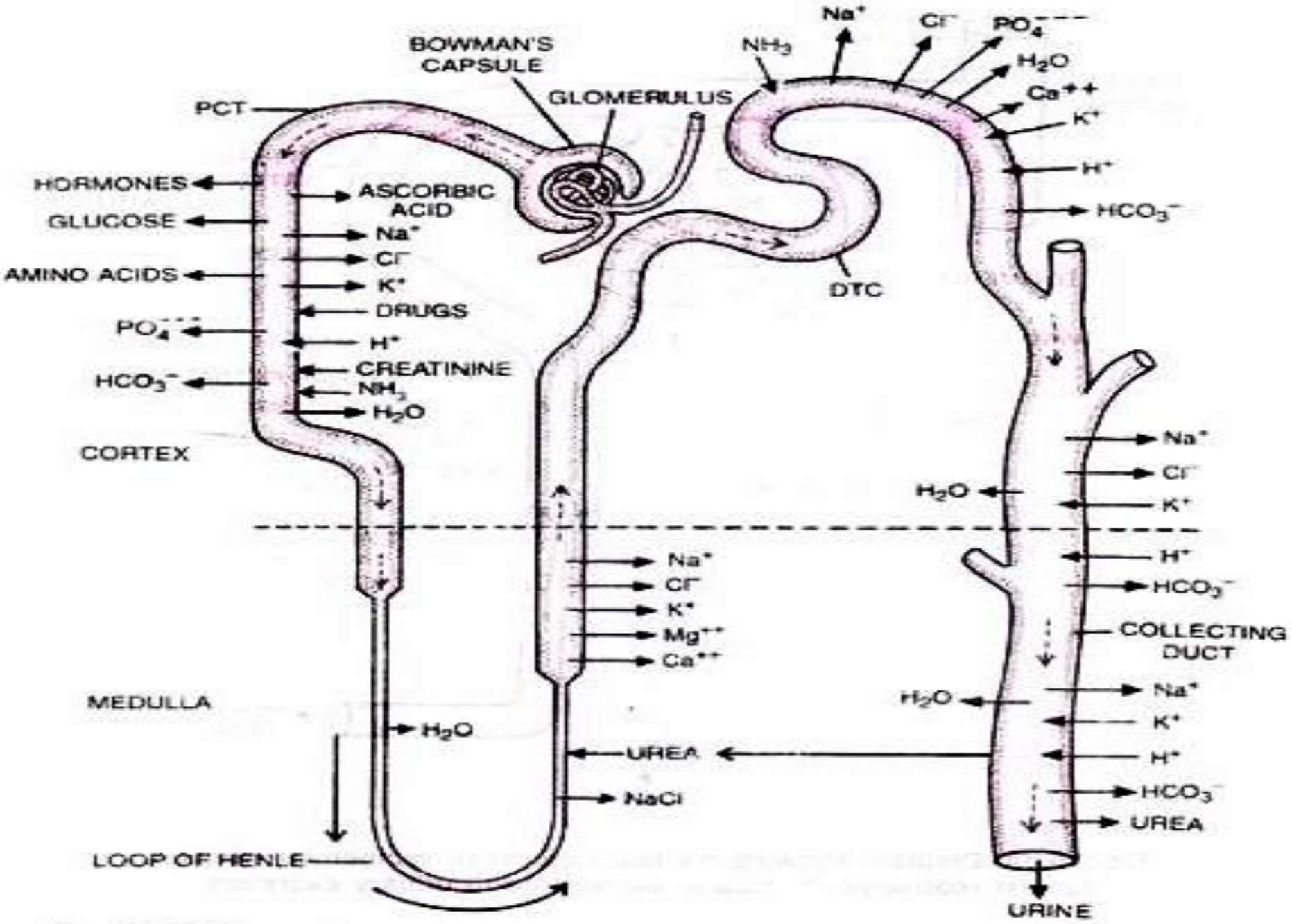


Fig. 19.15. Figure showing tubular reabsorption and secretion of major substances (Arrows indicate direction of movement of materials) in a mammalian nephron.

Hormonal Regulation of Diuresis

- Antidiuretic hormone (ADH)
- Aldosterone
- Sodium urethic hormone

Antidiuretic hormone (ADH)

- It activates hyaluronidase. It breaks down the hyaluronic acid of the connective tissue of the wall of the collecting ducts.
- ADH increases the formation of aquaporins. The pore size is increasing.
- As a result, the permeability of the wall of the collecting tubules for water increases.
- Reabsorption of water increases.
- As a result, diuresis decreases.

Aldosterone

- It increases the activity of the sodium-potassium pump in the distal convoluted tubules.
- Reabsorption of sodium increases.
- Water is reabsorbed after sodium according to the osmotic gradient.
- As a result, diuresis decreases.

Sodium Urethic Hormone

- It is produced in the wall of the right atrium.
- It is an antagonist of aldosterone.
- As a result, diuresis increases.

After studying the lecture, you need to be tested using the Google form service. Please fill in the fields full name, faculty and group number.

Test Link:

https://forms.gle/M1gwVEhAkWGrbF5TA