



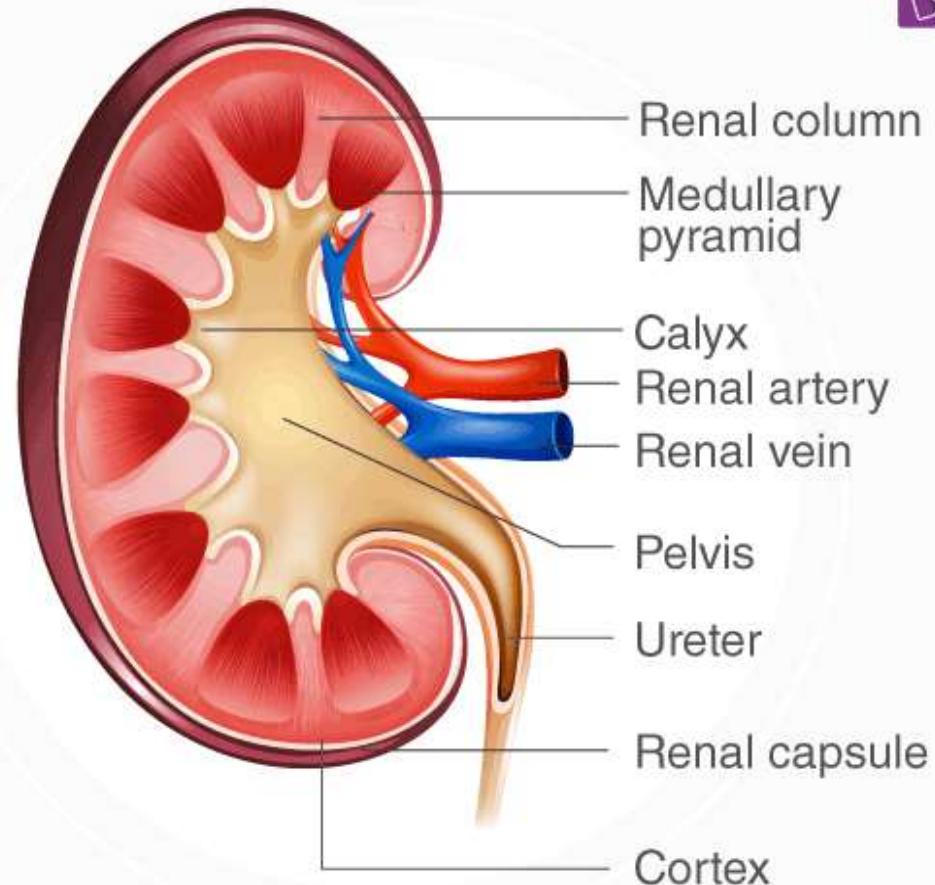
## UNIT II :

# Excretion:

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- Excretion is the process by which living organisms remove waste products of metabolism and other non-useful materials from their bodies to maintain homeostasis and prevent damage to the body.

# Structure of Kidney

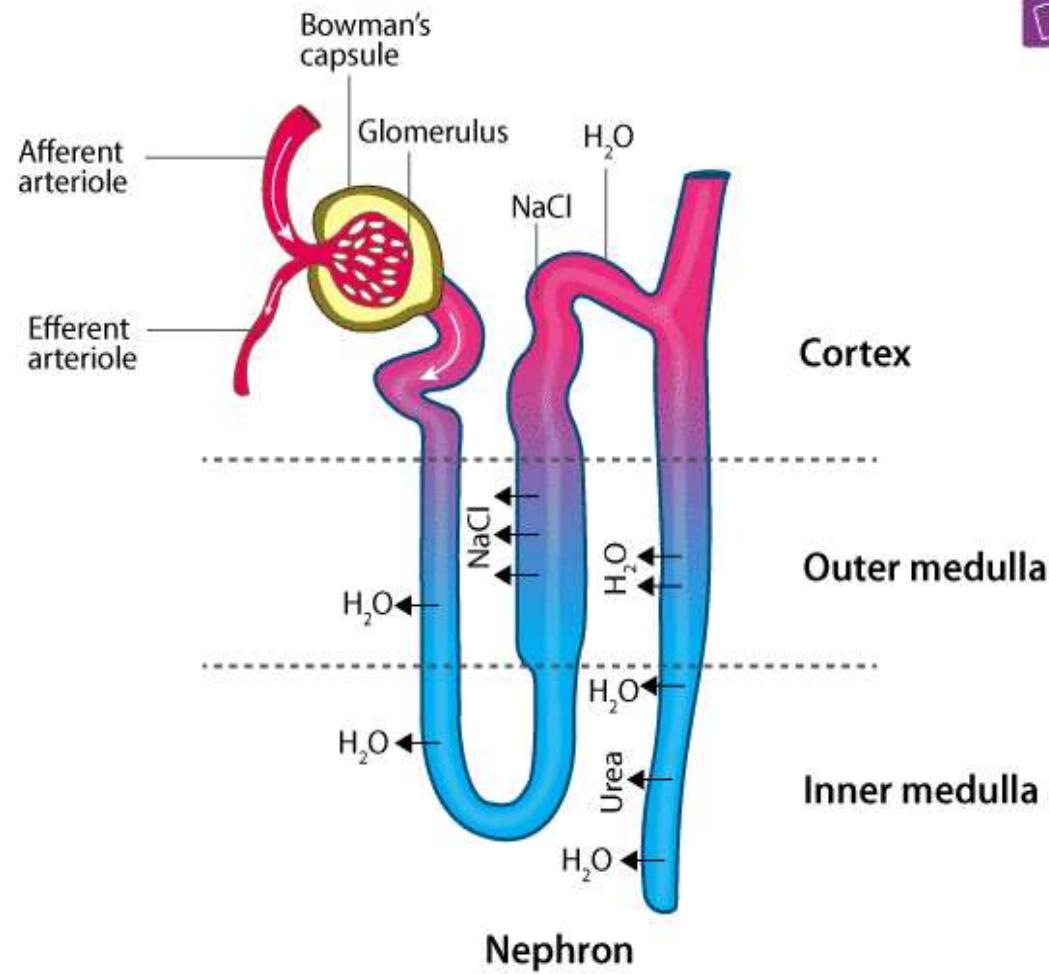


The kidney is a bean-shaped organ that plays a crucial role in filtering blood and producing urine. Here's a brief overview of its structure:

- **Cortex:** The outer layer of the kidney, containing the glomeruli, which are clusters of tiny blood vessels where filtration begins.
- **Medulla:** The inner part of the kidney, composed of cone-shaped structures called renal pyramids. The medulla contains the loops of Henle and collecting ducts, which help concentrate urine.

- **Renal Pelvis:** A funnel-shaped cavity that collects urine from the medulla and channels it into the ureter.
- **Nephrons:** The functional units of the kidney, each containing a glomerulus and a tubular system. Nephrons filter blood, reabsorb essential substances, and excrete waste products in the form of urine.
- **Ureter:** A tube that carries urine from the renal pelvis to the bladder.
- The kidney's structure is highly specialized for its role in filtering blood, maintaining electrolyte balance, and regulating blood pressure.

# Structure of Nephron.



- The nephron is the fundamental functional unit of the kidney, responsible for filtering blood, removing waste, and regulating various bodily functions. Each kidney contains approximately one million nephrons, and each nephron has a complex structure designed to efficiently perform these tasks. Here's a detailed breakdown of the nephron's structure:

## 1. Renal Corpuscle:

- The renal corpuscle is the site of blood filtration and consists of two main parts:
- **Glomerulus:** A network of tiny blood capillaries. Blood enters the glomerulus through the afferent arteriole and exits through the efferent arteriole. The glomerular capillaries are specialized for filtration, where water, ions, and small molecules are pushed out of the blood into the surrounding Bowman's capsule.
- **Bowman's Capsule (Glomerular Capsule):** A cup-shaped structure surrounding the glomerulus. It collects the filtrate (the fluid that has been filtered out of the blood) from the glomerulus. The inner layer of the capsule contains podocytes, which have foot-like projections that wrap around the glomerular capillaries and help filter blood.

## 2. Renal Tubule:

- The renal tubule is the segment where the filtrate is processed into urine. It consists of three main parts:
- **Proximal Convoluted Tubule (PCT):** The first segment of the renal tubule that is highly coiled and lined with microvilli to increase surface area for reabsorption. The PCT reabsorbs about 65-70% of filtered sodium, water, and other nutrients like glucose and amino acids.
- **Loop of Henle:** A U-shaped segment that dips into the medulla and then returns to the cortex. It has two limbs:
  - **Descending Limb:** Permeable to water but not to ions, allowing water to be reabsorbed into the surrounding medullary interstitium.
  - **Ascending Limb:** Impermeable to water but actively transports ions (sodium, potassium, and chloride) out into the medullary interstitium, contributing to the creation of a concentration gradient essential for the kidney's ability to produce concentrated urine.

- **Distal Convolute Tubule (DCT):** The coiled segment after the Loop of Henle. It's involved in the fine-tuning of electrolyte and acid-base balance by reabsorbing or secreting various ions and substances. The DCT adjusts the final composition of the filtrate, including potassium and sodium levels, and is influenced by hormones like aldosterone and antidiuretic hormone (ADH).

### 3. Collecting Ducts:

- The collecting ducts receive filtrate from multiple nephrons and are responsible for the final concentration of urine. They run through the renal pyramids in the medulla and merge to form larger ducts that eventually drain into the renal pelvis. Collecting ducts are also regulated by hormones such as ADH and aldosterone to adjust water and sodium reabsorption, thereby concentrating the urine and regulating blood volume and pressure.

- **Additional Components:**
- **Juxtaglomerular Apparatus (JGA):** Located where the DCT comes into contact with the glomerulus. It includes:
  - **Juxtaglomerular Cells:** These cells in the afferent arteriole produce renin, which is involved in blood pressure regulation.
  - **Macula Densa:** A group of specialized cells in the DCT that monitor sodium concentration in the filtrate and signal the juxtaglomerular cells to adjust renin secretion as needed.
- The nephron's structure allows it to effectively filter blood, reabsorb essential substances, and secrete waste products, maintaining homeostasis and balancing the body's fluid and electrolyte levels.

# Mechanism of Urine formation

- The mechanism of urine formation involves a series of processes that occur in the nephrons of the kidneys to filter blood, reabsorb necessary substances, and excrete waste products. This complex process can be broken down into three main stages: filtration, reabsorption, and secretion.

- **1. Filtration:**

- **Location:** Occurs in the **glomerulus** within the renal corpuscle.
- **Process:** Blood pressure forces water, ions, and small molecules from the blood in the glomerulus through the filtration membrane into the **Bowman's capsule**. The filtration membrane consists of:
  - **Fenestrated Endothelium:** Has pores that allow the passage of small molecules and prevents larger cells and proteins from passing through.
  - **Basement Membrane:** A gel-like layer that further restricts the passage of large proteins and cells.
  - **Podocytes:** Specialized cells with foot-like projections that wrap around the capillaries and form filtration slits, allowing selective filtration of smaller molecules.

**Filtrate:** The fluid that enters Bowman's capsule, containing water, electrolytes, glucose, amino acids, urea, and other small molecules.

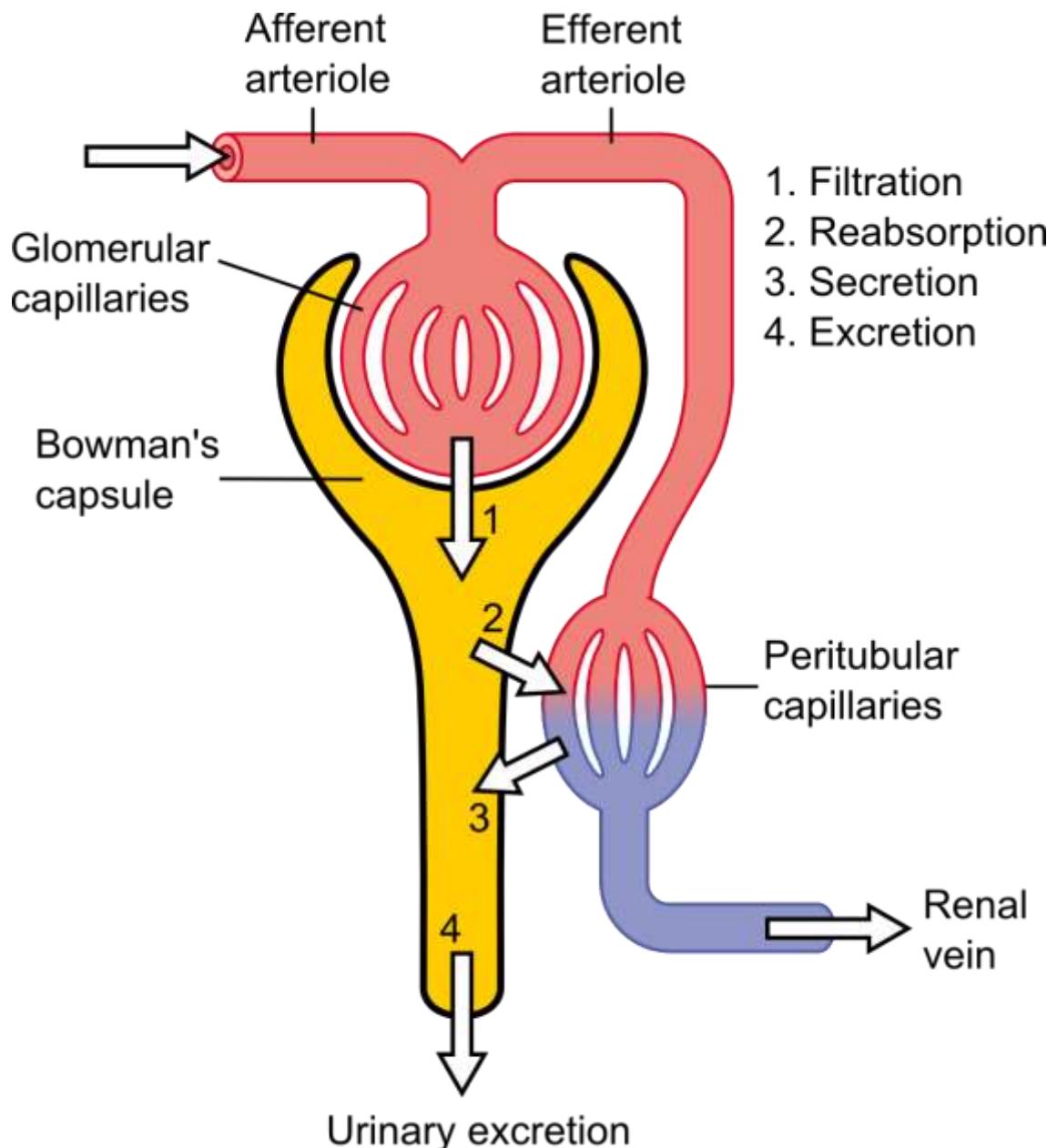
- **2. Reabsorption:**
- **Location:** Primarily occurs in the **proximal convoluted tubule (PCT)**, **Loop of Henle**, and **distal convoluted tubule (DCT)**.
- **Process:** The filtrate travels through the renal tubule, and various substances are reabsorbed back into the bloodstream:
  - **Proximal Convolute Tubule (PCT):** Reabsorbs about 65-70% of water, sodium, and chloride, as well as nearly all glucose and amino acids. This process involves both active and passive transport mechanisms.

- **Loop of Henle:**
  - **Descending Limb:** Highly permeable to water, which is reabsorbed into the surrounding medullary interstitium, concentrating the filtrate.
  - **Ascending Limb:** Impermeable to water but actively transports sodium, potassium, and chloride ions out of the filtrate into the interstitium, creating a high osmolarity gradient in the medulla that is crucial for water reabsorption.
- **Distal Convolved Tubule (DCT):** Fine-tunes the reabsorption of sodium, chloride, and calcium, regulated by hormones like aldosterone and parathyroid hormone (PTH). The DCT also helps in adjusting the acid-base balance by reabsorbing bicarbonate and secreting hydrogen ions.

- **3. Secretion:**
- **Location:** Mainly in the **distal convoluted tubule (DCT)** and **collecting ducts**.
- **Process:** Additional substances are secreted from the blood into the filtrate, including:
  - **Hydrogen Ions (H<sup>+</sup>):** To help maintain acid-base balance.
  - **Potassium Ions (K<sup>+</sup>):** Adjusted according to body needs, regulated by aldosterone.
  - **Waste Products:** Such as creatinine and certain drugs.
  - **Ammonium (NH<sub>4</sub><sup>+</sup>):** Produced from the metabolism of amino acids and helps in pH regulation.

# Final Steps:

- **Collecting Ducts:** Multiple nephrons' DCTs drain into the collecting ducts, where the final concentration of urine is adjusted. The collecting ducts are influenced by hormones such as:
  - **Antidiuretic Hormone (ADH):** Increases water reabsorption, making the urine more concentrated.
  - **Aldosterone:** Increases sodium reabsorption and potassium excretion, affecting the volume and composition of urine.
- **Urine Formation:** The final urine, now more concentrated, flows from the collecting ducts into the **renal pelvis**, through the **ureters**, and into the **bladder** for storage until it is excreted through the **urethra**.
- This process ensures that waste products and excess substances are efficiently removed from the body while retaining essential nutrients and maintaining fluid and electrolyte balance.



$$\text{Excretion} = \text{Filtration} - \text{Reabsorption} + \text{Secretion}$$

# Counter-current Mechanism.

- The counter-current mechanism is a physiological process in the kidneys that plays a critical role in the concentration of urine. It allows the kidneys to conserve water and maintain the body's fluid and electrolyte balance, particularly in response to varying hydration levels.

# Overview of the Counter-Current Mechanism

- The counter-current mechanism primarily involves two structures in the kidney:
- **Loop of Henle** (particularly the ascending and descending limbs)
- **Vasa Recta** (the capillary network surrounding the Loop of Henle)

# Steps in the Counter-Current Mechanism

## 1. Descending Limb of the Loop of Henle:

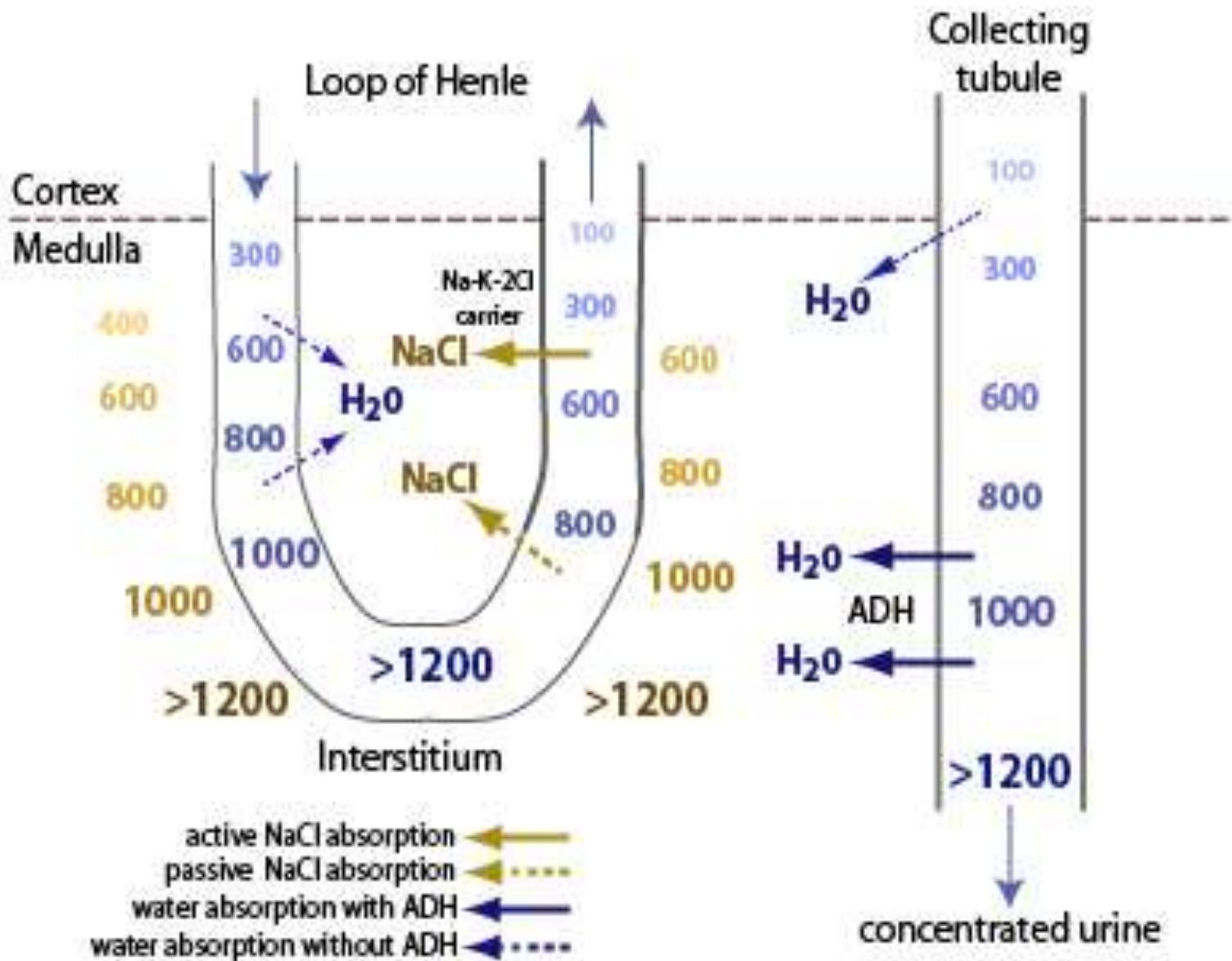
- The descending limb is permeable to water but impermeable to solutes (like sodium and chloride ions).
- As filtrate moves down the descending limb, water is drawn out into the surrounding medullary interstitium (the space outside the Loop of Henle), which has a high osmolarity (concentration of solutes).
- This leads to the filtrate becoming more concentrated as it reaches the bottom of the Loop of Henle.

## 2. Ascending Limb of the Loop of Henle:

- The ascending limb is impermeable to water but permeable to solutes.
- As the filtrate ascends, sodium and chloride ions are actively transported out of the filtrate into the medullary interstitium, decreasing the filtrate's osmolarity.
- The filtrate becomes more dilute as it moves upward because water cannot follow the solutes out of the tubule.

### 3. Role of the Vasa Recta:

- The vasa recta, a network of blood vessels surrounding the Loop of Henle, acts as a counter-current exchanger.
- Blood in the vasa recta flows in the opposite direction to the filtrate in the Loop of Henle.
- As the blood descends into the medulla, it picks up solutes and loses water due to the high osmolarity of the surrounding interstitium.
- As it ascends back toward the cortex, it loses solutes and gains water. This maintains the osmotic gradient in the medulla and prevents it from being washed away.



# Result of the Counter-Current Mechanism

- The counter-current mechanism creates and maintains a gradient of increasing osmolarity from the cortex to the medulla of the kidney.
- This gradient is essential for the kidney's ability to produce concentrated urine. When the body needs to conserve water,
- antidiuretic hormone (ADH) increases the permeability of the collecting ducts to water, allowing more water to be reabsorbed into the bloodstream, resulting in concentrated urine.

# Summary

- The counter-current mechanism in the kidney ensures that a high concentration gradient is maintained in the medulla, allowing for efficient reabsorption of water and concentration of urine.
- This mechanism is crucial for the kidney's ability to regulate the body's water balance and excrete waste products in a minimal volume of water.

# Cardiovascular system:

## Composition and Function of Blood:

Blood is a complex and vital fluid in the human body, composed of several key components that each serve specific functions:

### 1. Plasma

- **Volume Contribution:** Plasma makes up about 55% of total blood volume.
- **Composition:**
  - **Water:** Roughly 90% of plasma is water, which serves as a solvent.
  - **Proteins:** Plasma contains various proteins, including:
    - **Albumin:** Helps maintain the osmotic pressure that regulates the exchange of water between blood vessels and tissues.
    - **Fibrinogen:** A clotting factor that helps in the formation of blood clots.
    - **Globulins:** These include antibodies and other proteins involved in immune responses and transport functions.



**Electrolytes:** Sodium, potassium, calcium, chloride, and bicarbonate ions, which help maintain pH balance and proper nerve and muscle function.

**Nutrients:** Glucose, amino acids, vitamins, and lipids, which are distributed to cells throughout the body.

**Waste Products:** Urea, creatinine, and other metabolic waste products, which are transported to the kidneys for excretion.

**Hormones and Enzymes:** Plasma carries hormones and enzymes that regulate various physiological processes.

## 2. Red Blood Cells (Erythrocytes)

- **Volume Contribution:** They account for about 40-45% of blood volume, a measure known as the hematocrit.
- **Function:** Red blood cells are primarily responsible for transporting oxygen from the lungs to the tissues and carrying carbon dioxide back to the lungs for exhalation.
- **Key Component: Hemoglobin:** A protein that binds oxygen molecules in the lungs and releases them in tissues. Hemoglobin also binds to carbon dioxide for transport back to the lungs.

### 3. White Blood Cells (Leukocytes)

- **Volume Contribution:** Less than 1% of total blood volume.
- **Function:** White blood cells are crucial for the immune system, helping to protect the body against infections, foreign invaders, and abnormal cells.
- **Types:**
  - **Neutrophils:** The most abundant type, involved in the immediate response to infection.
  - **Lymphocytes:** Include T cells and B cells, which are essential for adaptive immune responses.
  - **Monocytes:** Develop into macrophages and dendritic cells, which help in phagocytosis (ingesting harmful particles) and antigen presentation.
  - **Eosinophils and Basophils:** Involved in allergic reactions and responses to parasites.

## 4. Platelets (Thrombocytes)

- **Volume Contribution:** Less than 1% of blood volume.
- **Function:** Platelets are small cell fragments that play a critical role in blood clotting. When a blood vessel is injured, platelets gather at the site and form a plug by clumping together, which helps stop bleeding. They also release chemicals that further the clotting process.



### Plasma

**Constituent** Water, Ions (blood electrolytes), plasma proteins, Substances transported by blood

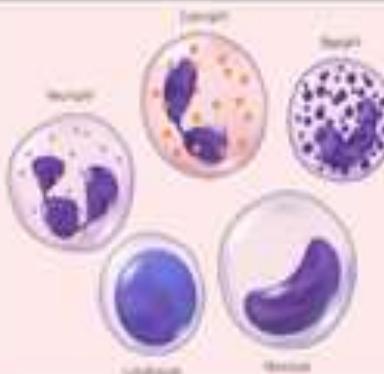
**Functions** Solvent for carrying other substances, Osmotic balance, pH buffering and regulation of membrane permeability, Clotting and Defense.



### Platelets

**Number** per  $\mu\text{l}$  ( $\text{mm}^3$ ) of blood 250,000-400,000

**Functions** Blood clotting



### White blood cells

**Number** per  $\mu\text{l}$  ( $\text{mm}^3$ ) of blood 5,000-10,000

**Functions** Defence and immunity



### Red blood cells

**Number** per  $\mu\text{l}$  ( $\text{mm}^3$ ) of blood 5-6 million

**Functions** Transport oxygen and help transport carbon dioxide

# Summary

- **Blood Composition:** Blood is about 55% plasma and 45% cells, which include red blood cells, white blood cells, and platelets.
- **Functions:** Blood transports oxygen, nutrients, hormones, and waste products throughout the body, while also playing key roles in immune defense, regulation of body temperature, pH balance, and coagulation.
- Each component of blood is essential to maintaining homeostasis and ensuring the proper functioning of the body's systems.

# Types of heart in vertebrates: Neurogenic

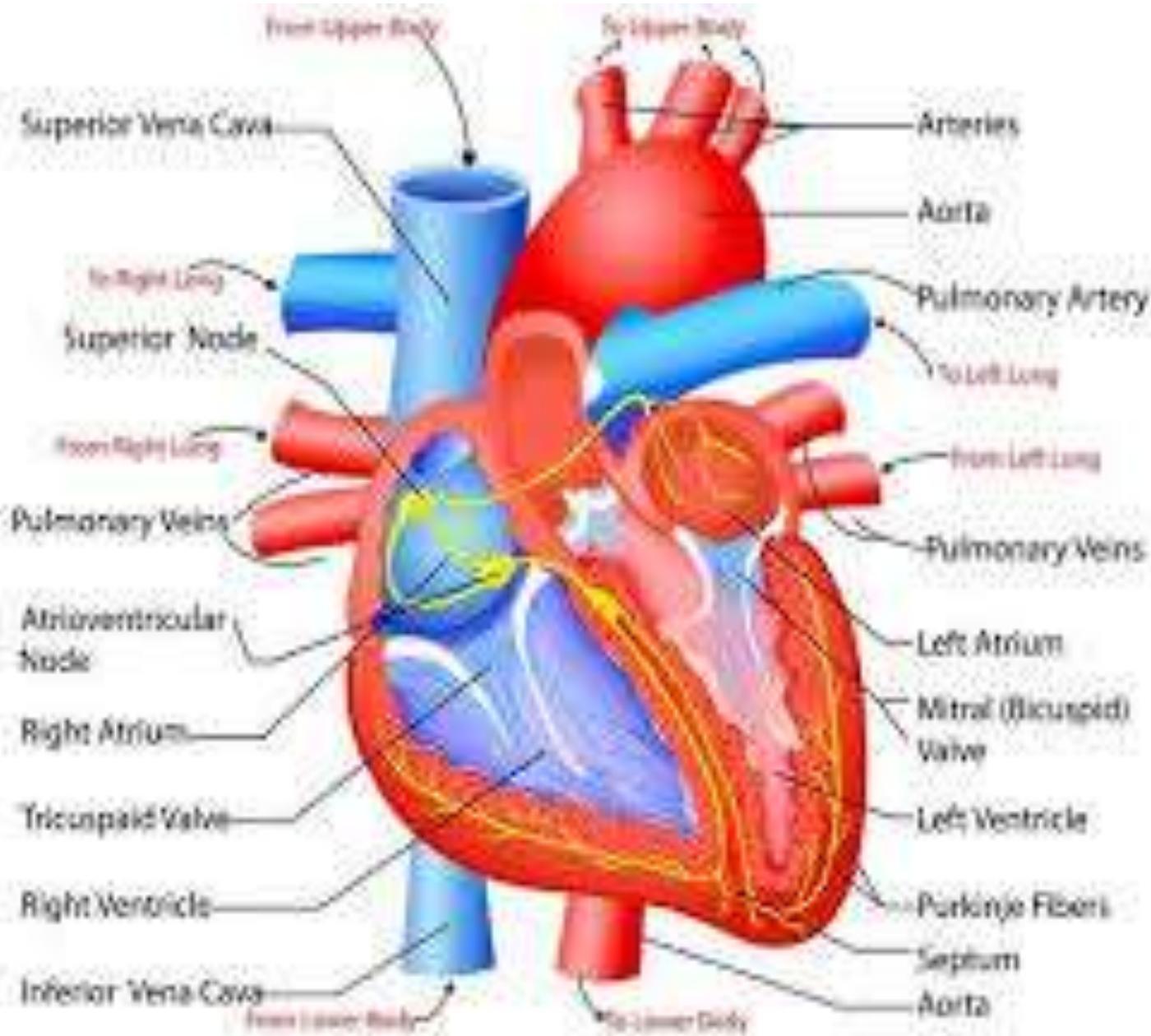
- In vertebrates, hearts are generally classified based on how their heartbeat is initiated: neurogenic or myogenic.
- **Neurogenic hearts** are typically found in some invertebrates, like arthropods, and are less common in vertebrates. However, it's important to note that in vertebrates, hearts are usually myogenic. Nevertheless, discussing neurogenic hearts provides a good contrast to the myogenic hearts seen in vertebrates.

# Neurogenic Heart Overview

- **Heartbeat Initiation:** In a neurogenic heart, the heartbeat is initiated by nerve impulses. This means that the heart's rhythm is controlled by nervous system signals rather than being generated by the heart muscle itself.
- **Location of Pacemaker:** The pacemaker cells, which regulate the heartbeat, are located in the nervous system rather than within the heart muscle.
- **Mechanism:**
  - Nerves connected to the heart send regular signals to contract.
  - If the nerve supply to the heart is cut off, the heart would typically stop beating.

# Example in Invertebrates

- **Arthropods (e.g., Crustaceans, Insects):** Many arthropods have neurogenic hearts. In these animals, the heart is controlled by the central nervous system, specifically through a group of neurons called the cardiac ganglion.
  - The cardiac ganglion generates rhythmic nerve impulses that cause the heart muscle to contract and pump blood.



# Myogenic heart

- A myogenic heart is a type of heart where the impulse for contraction originates from the heart muscle itself, specifically from specialized cells, rather than being dependent on external nervous system input.
- In such hearts, the muscle cells are capable of generating rhythmic contractions autonomously.
- This contrasts with a neurogenic heart, where the contraction is controlled by nerve impulses.

# Key Features of a Myogenic Heart:

- Pacemaker Cells: The contraction is initiated by specialized cells, usually located in the sinoatrial (SA) node, often referred to as the heart's natural pacemaker. These cells spontaneously generate electrical impulses that cause the heart to beat.
- Autonomous Function: The heart maintains its rhythm independently of nervous system control, although external factors like hormones and the autonomic nervous system can influence the rate and strength of contractions.

- Vertebrate Hearts: Most vertebrates, including humans, have a myogenic heart. In humans, the cardiac cycle begins with the SA node, which sets the pace for the entire heart.
- Conduction System: After the SA node generates an electrical impulse, it spreads through the atria, causing them to contract, and then travels to the atrioventricular (AV) node, and through the Purkinje fibers to the ventricles, ensuring coordinated heartbeats.

## Advantages:

- The heart can continue beating even if nerve connections are severed.
- The pacemaker can adjust the rate of heartbeat based on physiological needs, such as during exercise or rest.
- ❖ In summary, the myogenic heart operates independently of neural input, using intrinsic mechanisms to generate and regulate its rhythmic contractions, ensuring the continuous circulation of blood throughout the body.

- Examples:

An example of a myogenic heart is the human heart. Other vertebrates, such as mammals, birds, reptiles, and amphibians, also have myogenic hearts.

