

Urinary System: Renal Physiology for Medical Students

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Reference: Guyton

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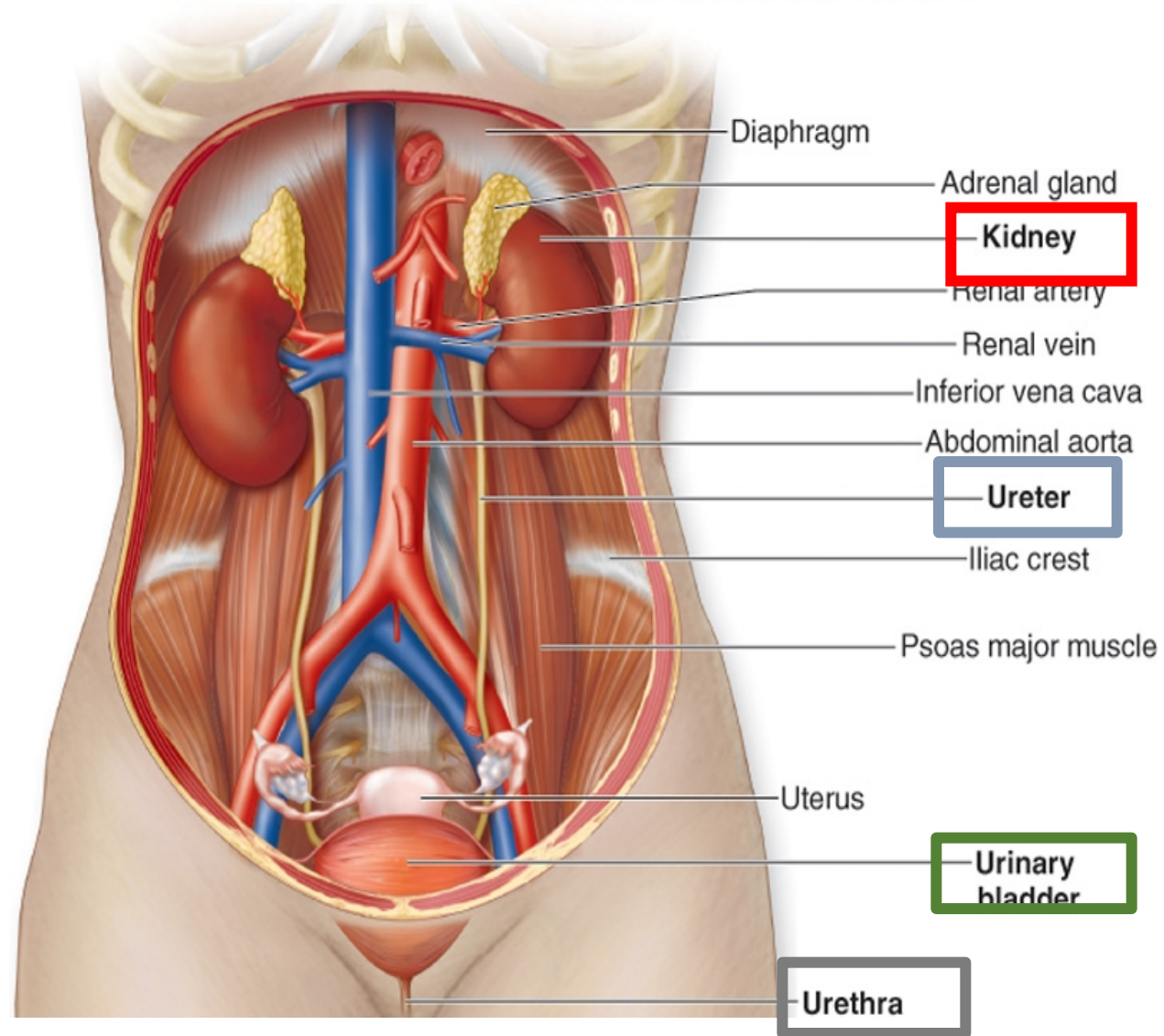
Learning Objectives

- Identify the functions of the urinary system, particularly the kidneys.
- Describe the external and internal anatomical features of the kidneys.
- Describe the structure of the nephron including the renal corpuscles and the renal tubules.
- Dissect the blood supply of the kidney including nephrons blood supply.
- Understand the relation between the structure and function of the nephron unit.

The Urinary System

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- The **Kidneys** do most of the work of the urinary system, while other parts serve as passageways or storage organs
- The **ureter** transport urine from the kidneys to the urinary bladder.
- The **urinary bladder** stores urine.
- The **urethra** discharges urine from the body.



Urinary System Function

- **Filters Waste Products from Blood**

-Excretion of water and sodium chloride (NaCl) is regulated in conjunction with cardiovascular, endocrine, & central nervous system

-The urinary system eliminates in the urine different waste products such as :

1. **ammonia** and **urea** (both formed when amino acids are broken down),
2. **uric acid** (formed when nucleic acids are broken down),
3. **creatinine** (from muscles).
4. **end products of hemoglobin metabolism, hormone metabolites foreign substances**
(e.g., drugs, pesticides, & other chemicals ingested in the food)

-The blood is filtered by the kidney through 3 processes called **filtration, reabsorption, and secretion.**

The wastes leave the body as **urine.**

Urinary System Function

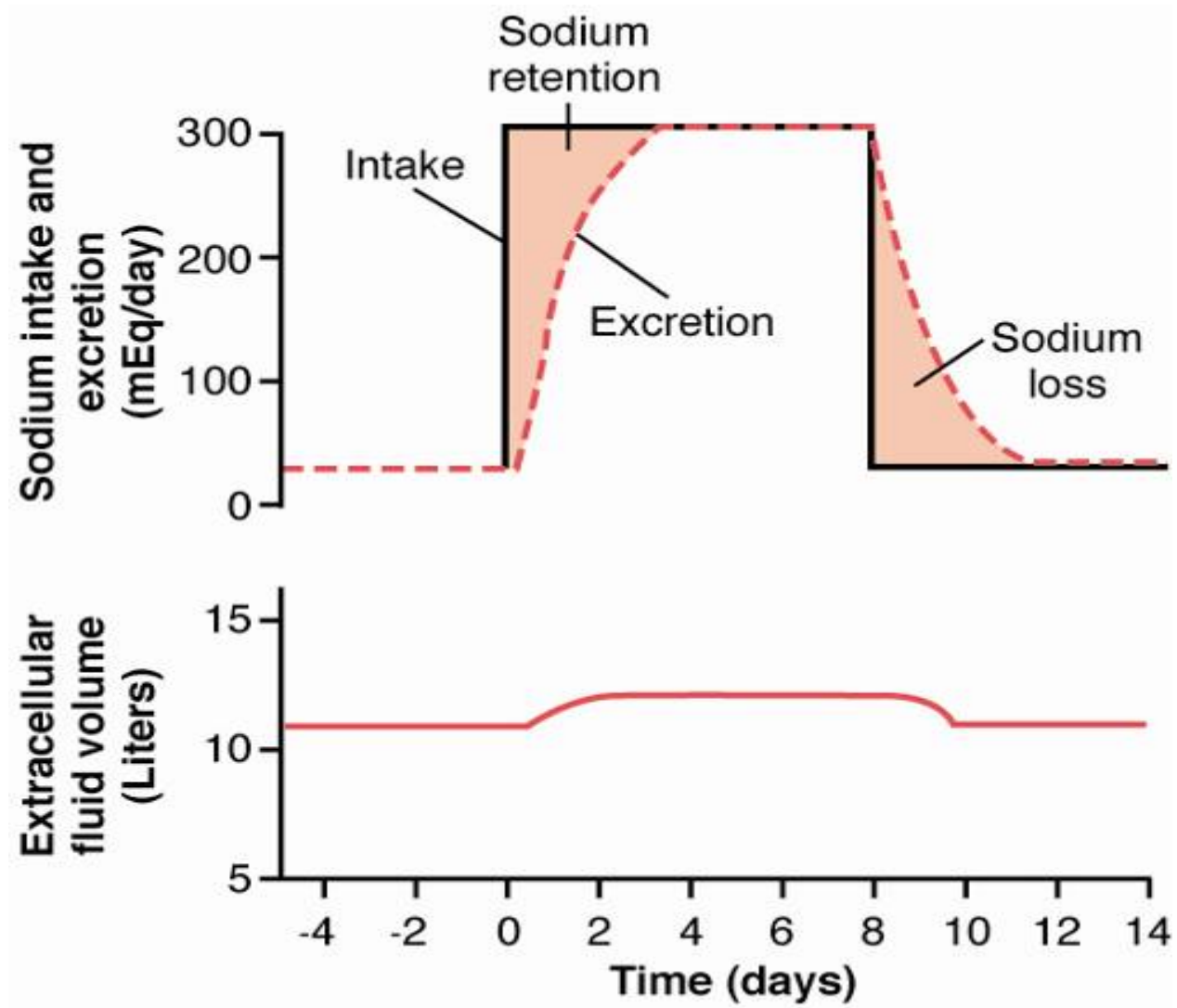
- **Conserves Valuable Nutrients**

The urinary system ensures glucose, amino acids and other valuable nutrients are not lost from the urine. Kidneys can also use glutamine to release glucose in gluconeogenesis.

- **Regulates Ion Levels in the Plasma**

The urinary system regulates ion (electrolyte) levels in the plasma by regulating the amount of sodium, potassium, chloride and other ions lost in the urine.

Effect of increasing sodium intake 10-fold on urinary sodium excretion and extracellular fluid volume



Urinary System Function

- **Regulates Blood pH**

- The urinary system regulates blood pH by regulating the number of H^+ and bicarbonate ions (HCO_3^-) lost in the urine.

- The kidneys work in concert with lungs to regulate the pH in a narrow limits of buffers within body fluids.

Urinary System Function

- **Regulates Blood Volume**

The urinary system regulates blood volume by:

- 1) releasing **renin**, a hormone that after a series of reactions eventually restricts salt and water loss at the kidneys.
- 2) adjusting the volume of water lost in the urine

Urinary System Function

- **Regulates RBC Production**

- If oxygen levels in the blood are low, the kidneys release **erythropoietin**, a hormone that stimulates the hemocytoblasts (stem cells in the bone marrow) to increase red blood cell formation. Having more RBCs allows the blood to transport more oxygen.

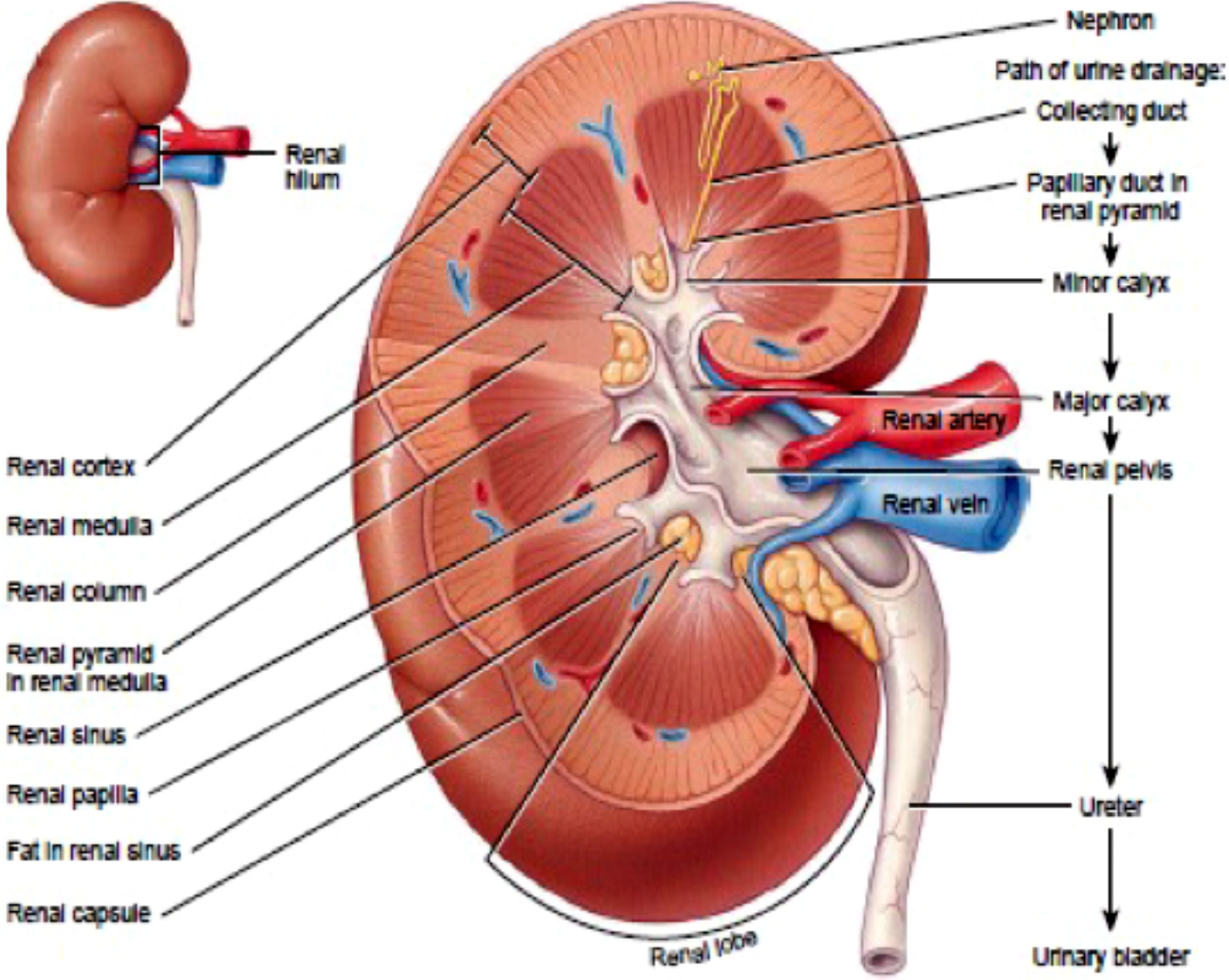
Urinary System Function

- **Stores Urine**
 - The **bladder** stores the urine until it is convenient to excrete it.
- **Excretes Urine:** The **urethra** transports urine from the urinary bladder to the outside of the body.

Urinary System Function

- **Produces and secretes hormones:**
 - **Calcitriol:** The active form of vitamin D.
 - **Renin:** activates the renin-angiotensin-aldosterone system, thus regulating blood pressure regulation & Na⁺, K⁺ balance.
 - **Prostaglandins/kinins:** bradykinin = vasoactive, leading to modulation of renal blood flow & along with angiotensin II affect the systemic blood flow
 - **Erythropoietin:** stimulates red blood cell formation by bone marrow

Kidney Structure



(a) Frontal section of right kidney

Kidneys and urinary system

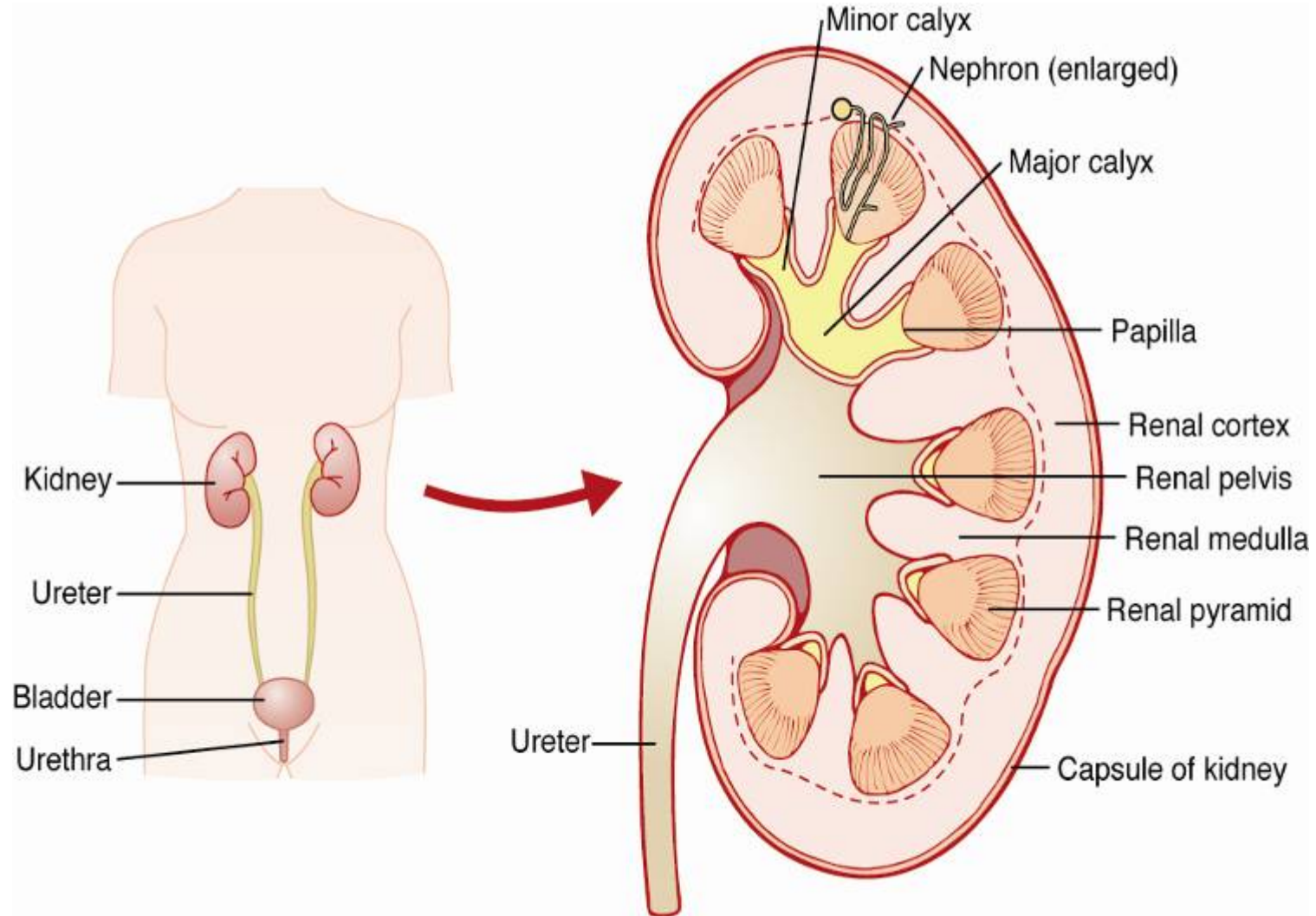


Figure 26-3

Major blood vessels of the kidney

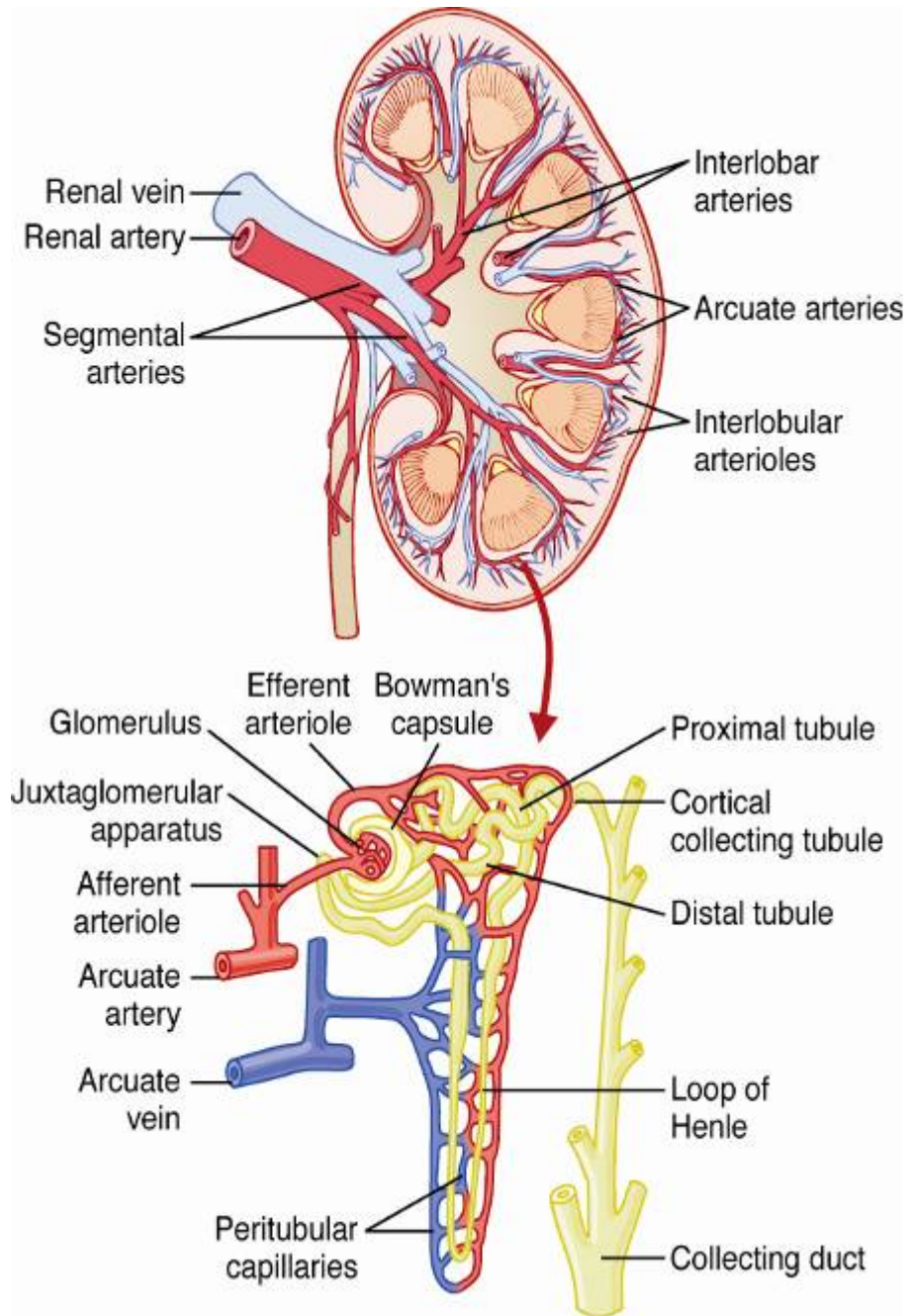


Figure 26-3

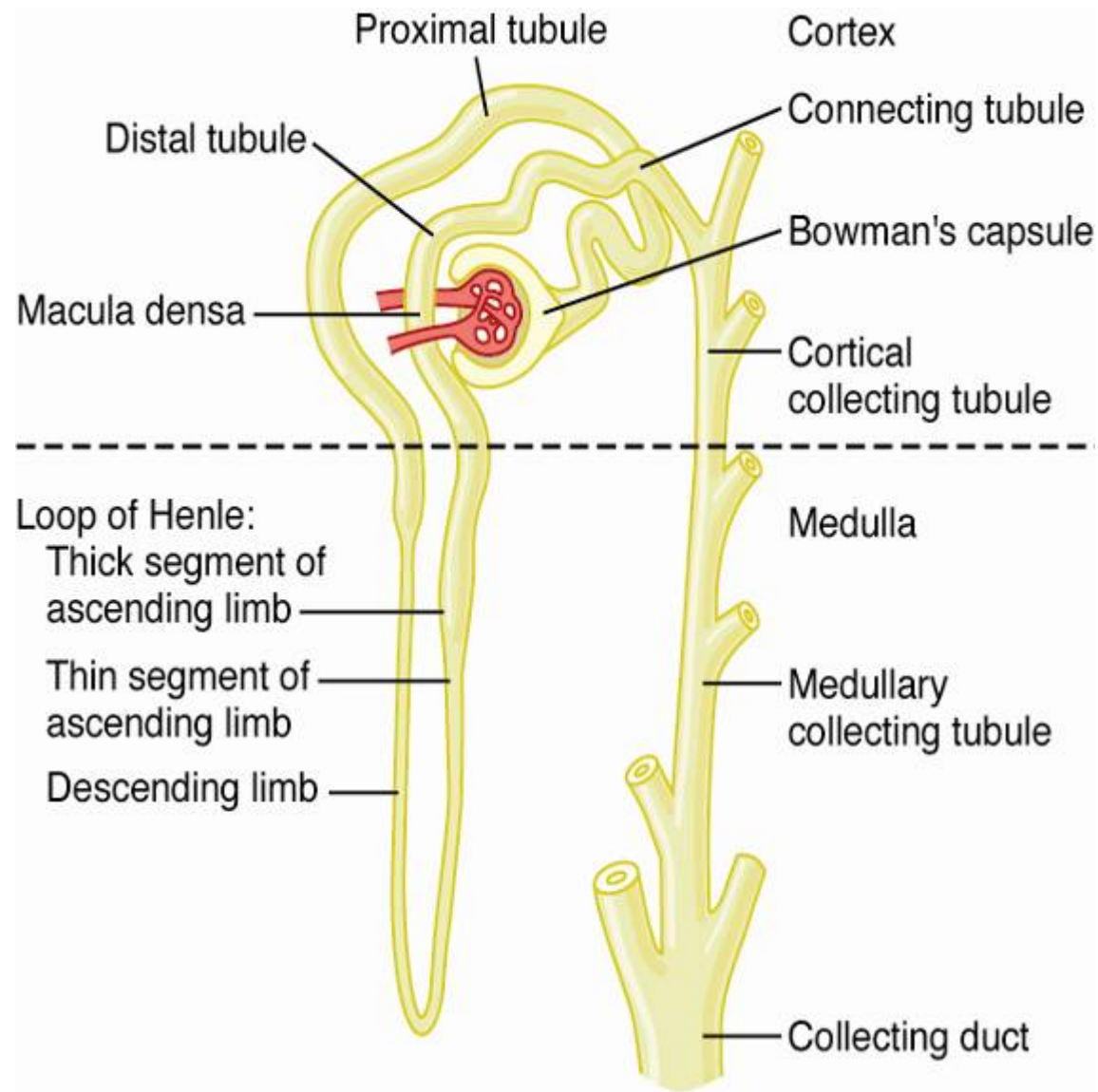


Figure 26-4

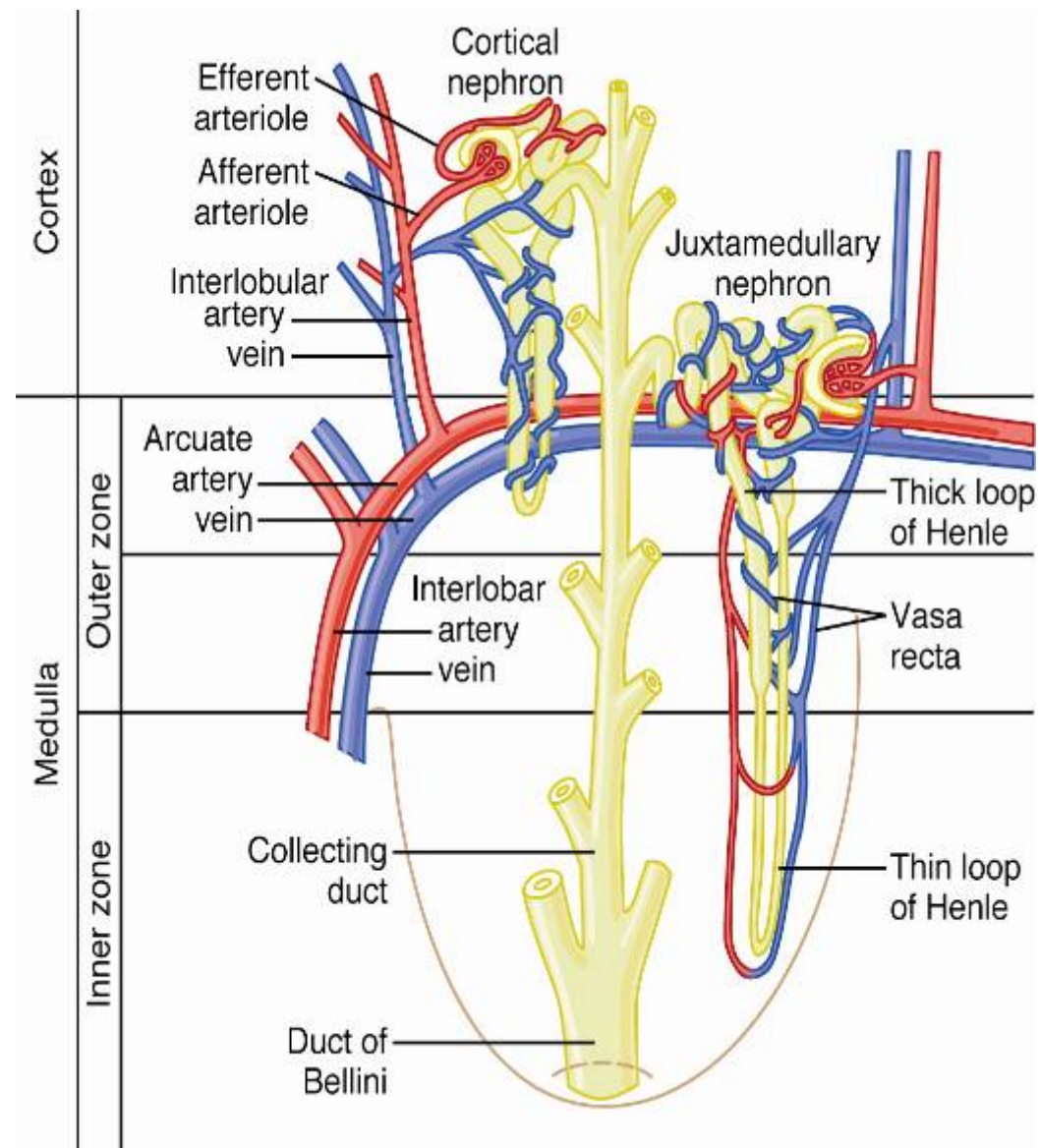
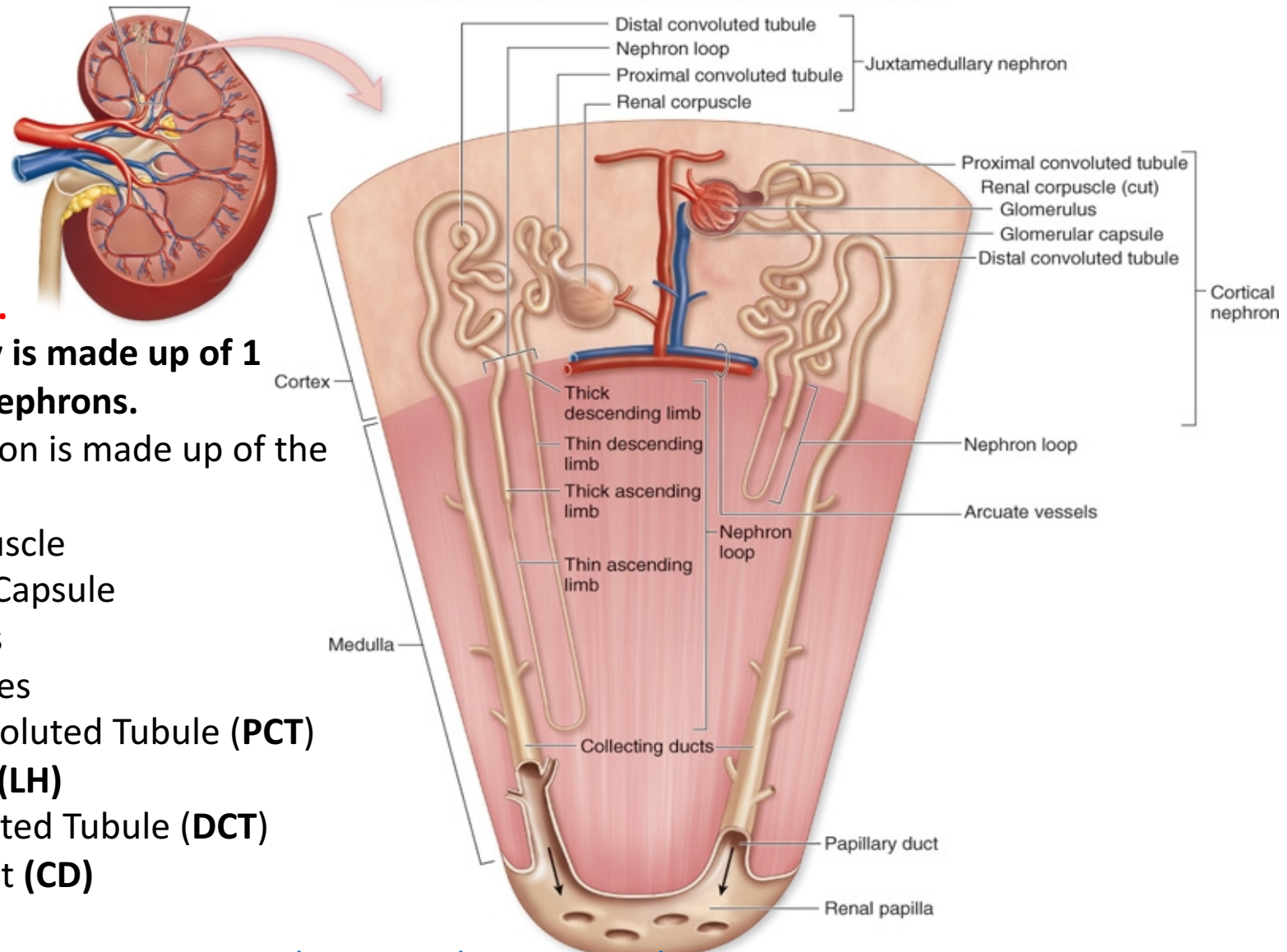


Figure 26-5

The Functional Unit of The Kidney?

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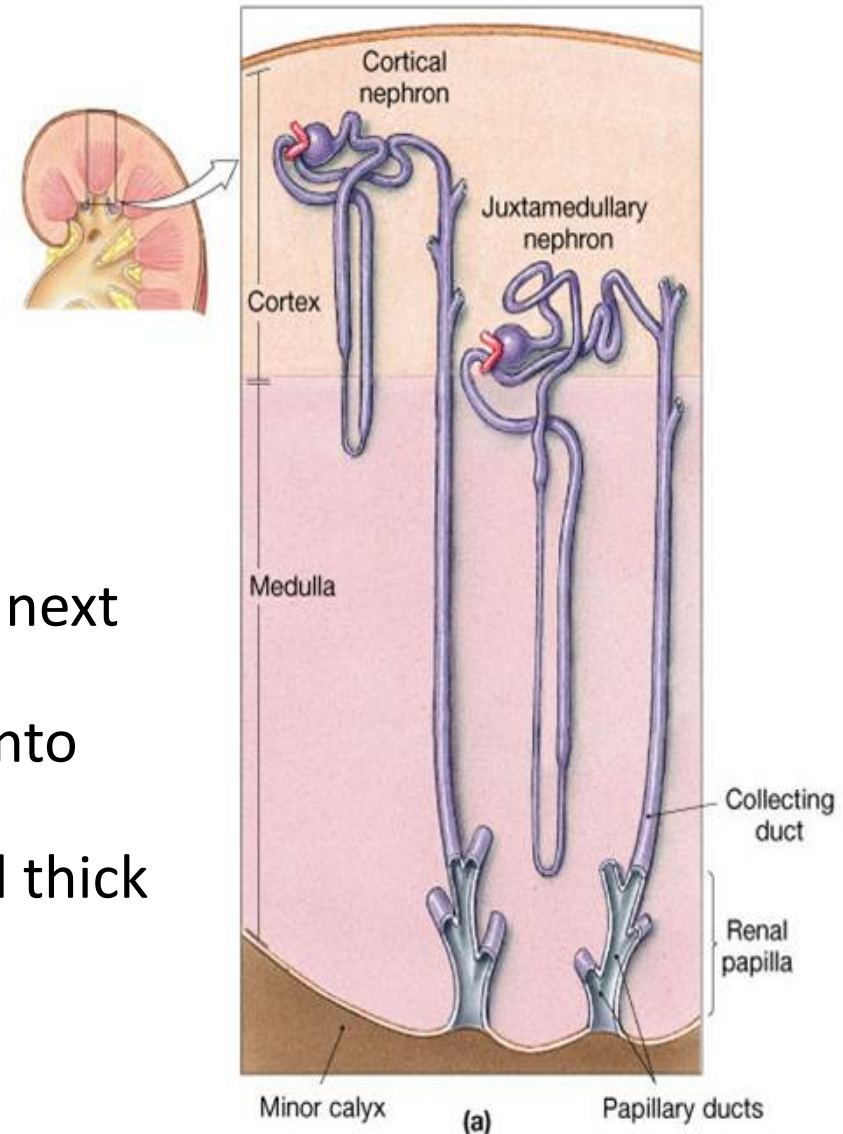


Is the nephron.

- Each kidney is made up of **1 million of nephrons.**
- Each nephron is made up of the following:
 - ❑ Renal Corpuscle
 - Bowman's Capsule
 - Glomerulus
 - ❑ Renal Tubules
 - Proximal Convoluted Tubule (**PCT**)
 - Loop of Henle(**LH**)
 - Distal Convoluted Tubule (**DCT**)
 - Collecting Duct (**CD**)

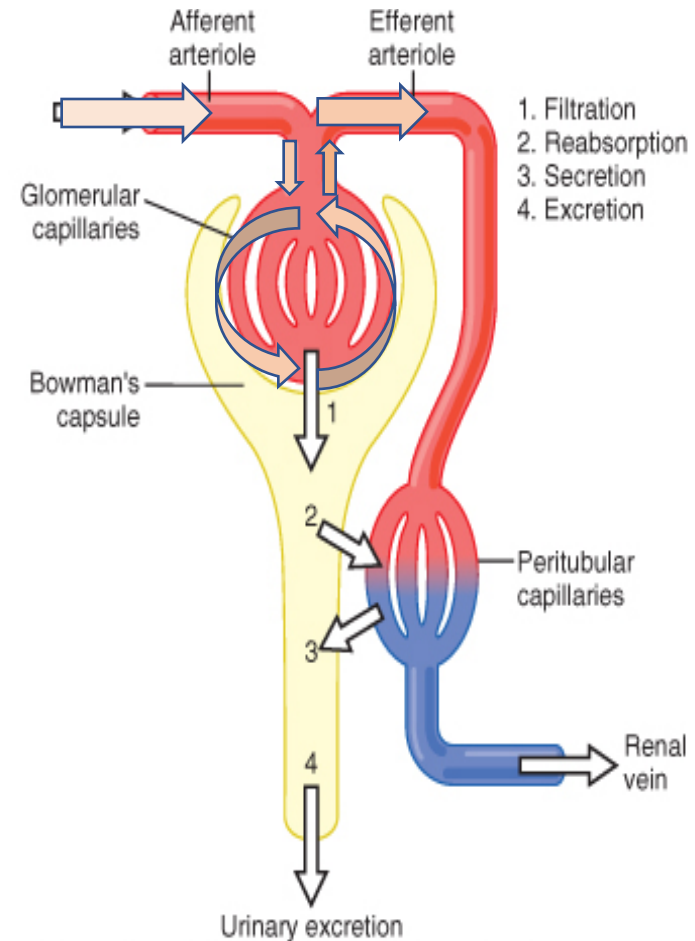
Types of Nephrons

- **Cortical nephrons**
 - -~85% of all nephrons.
 - Are located in the cortex.
 - short Loop of Henle.
- **Juxtamedullary nephrons**
 - Are deep in cortex closer (juxta = next to) the renal medulla.
 - The loops of Henle extend deep into the medulla (renal pyramids).
 - Ascending limb contains thin and thick ascending portions.



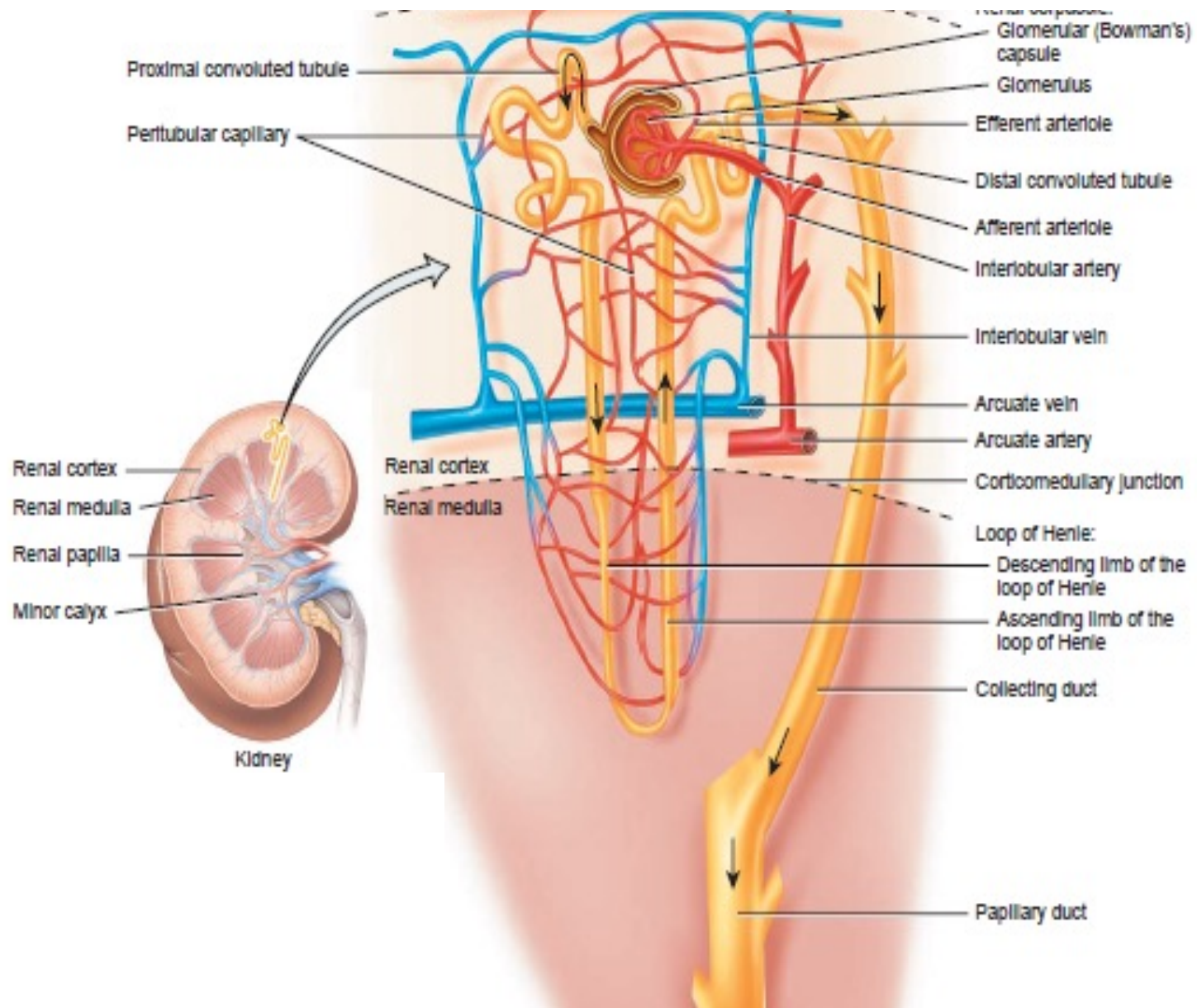
Nephron Blood Supply

- Blood travels from the **afferent arteriole** to a ball of capillaries in the nephron called a **glomerulus**
- Blood leaves the nephron via the **efferent arteriole**
- Blood travels from efferent arteriole to the **peritubular capillaries** and **vasa recta**

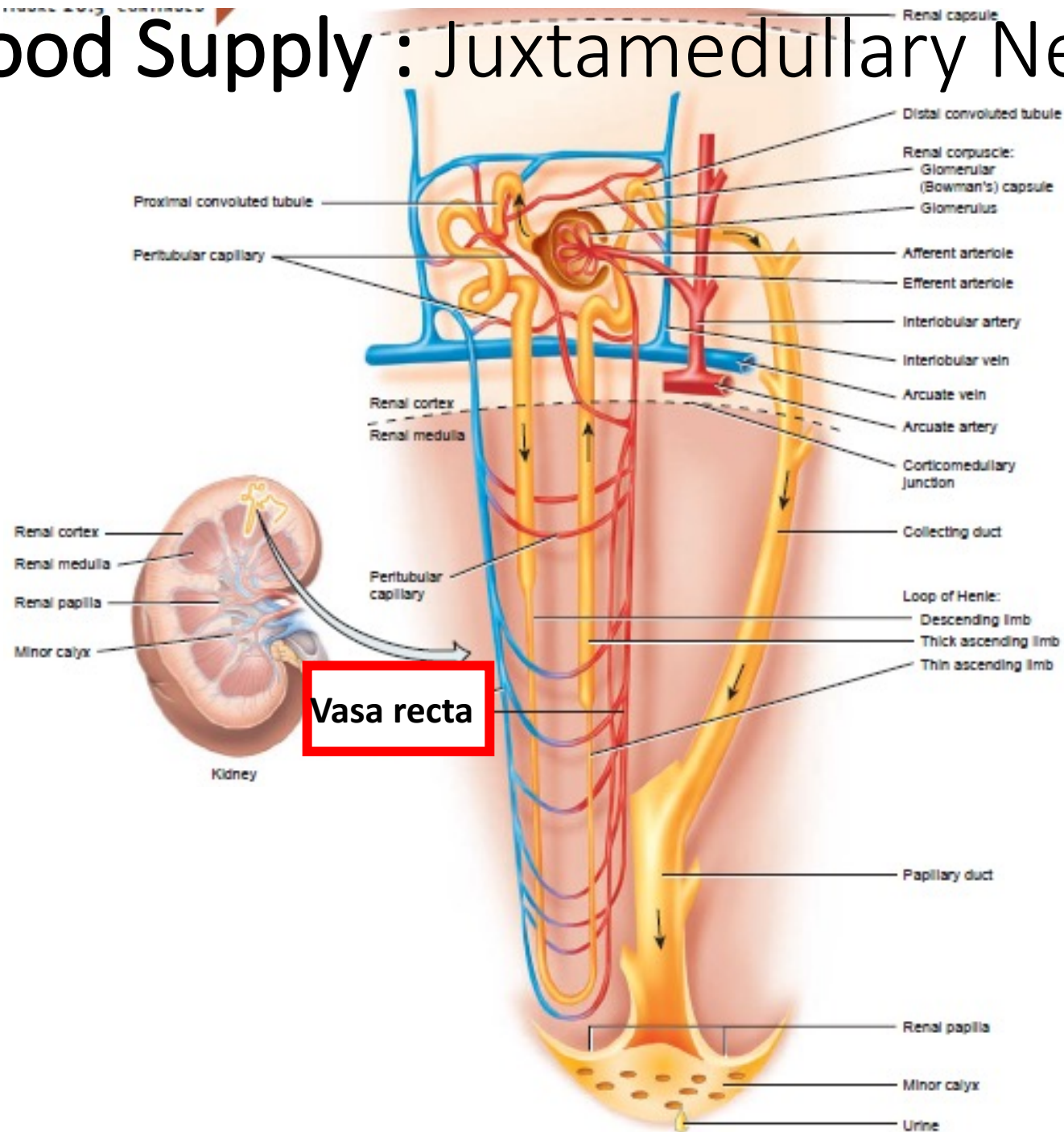


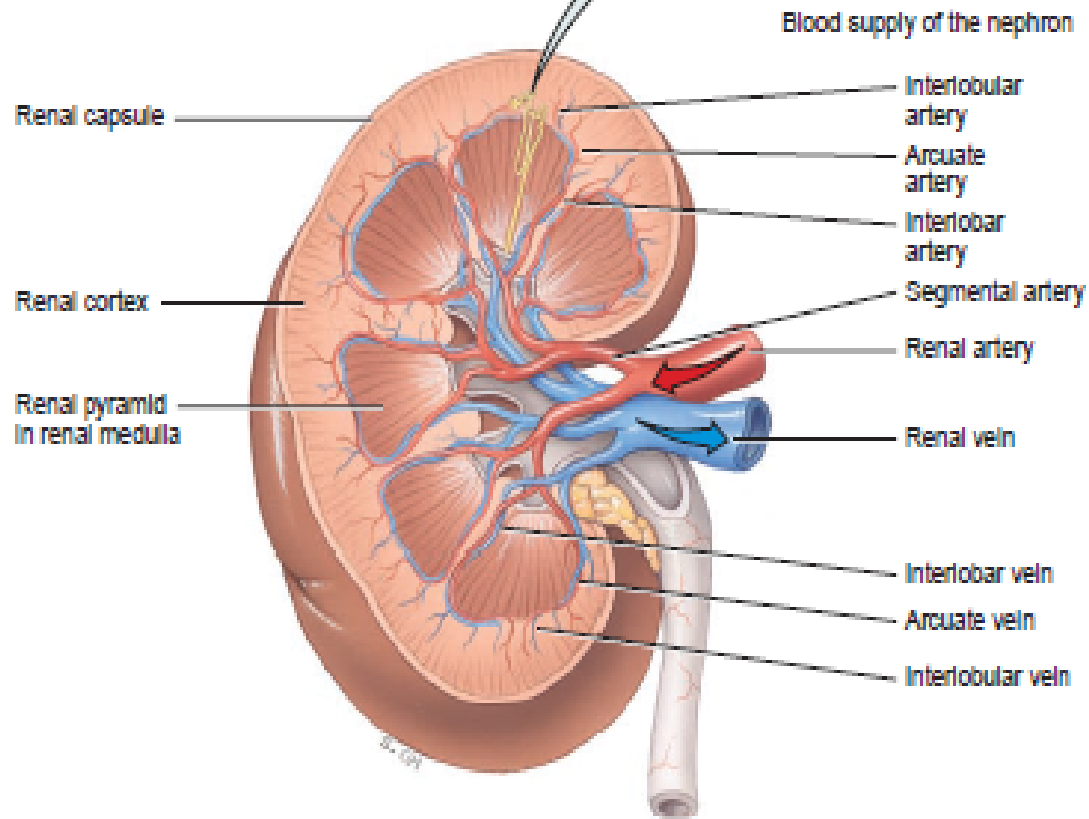
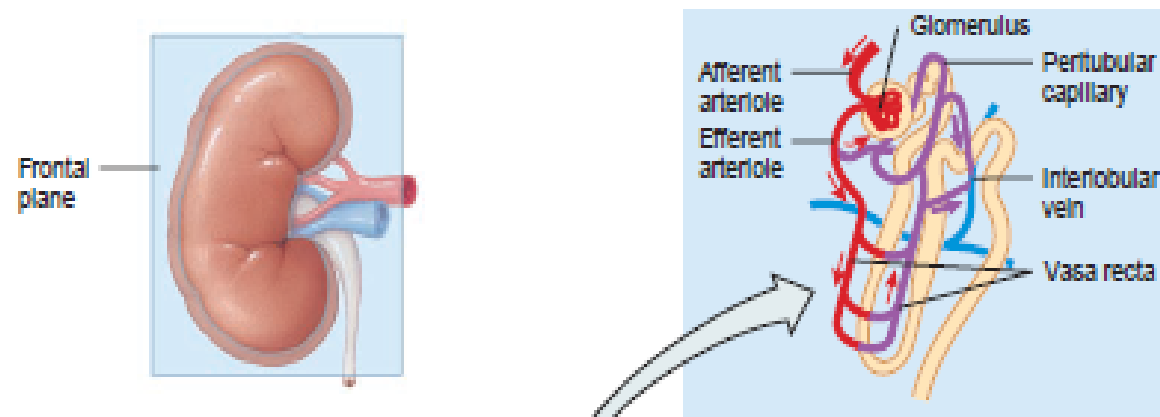
Blood Flow →
Filtrate Flow →

Blood Supply: Cortical Nephron

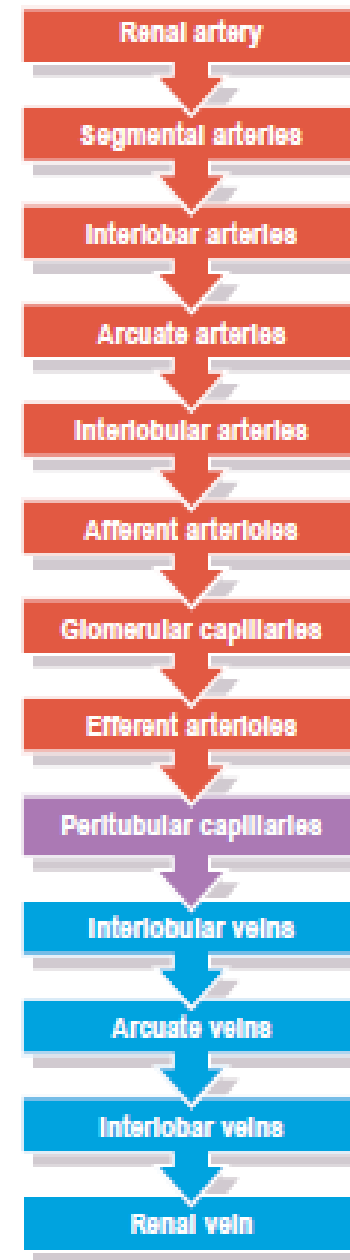


Blood Supply : Juxtamedullary Nephron



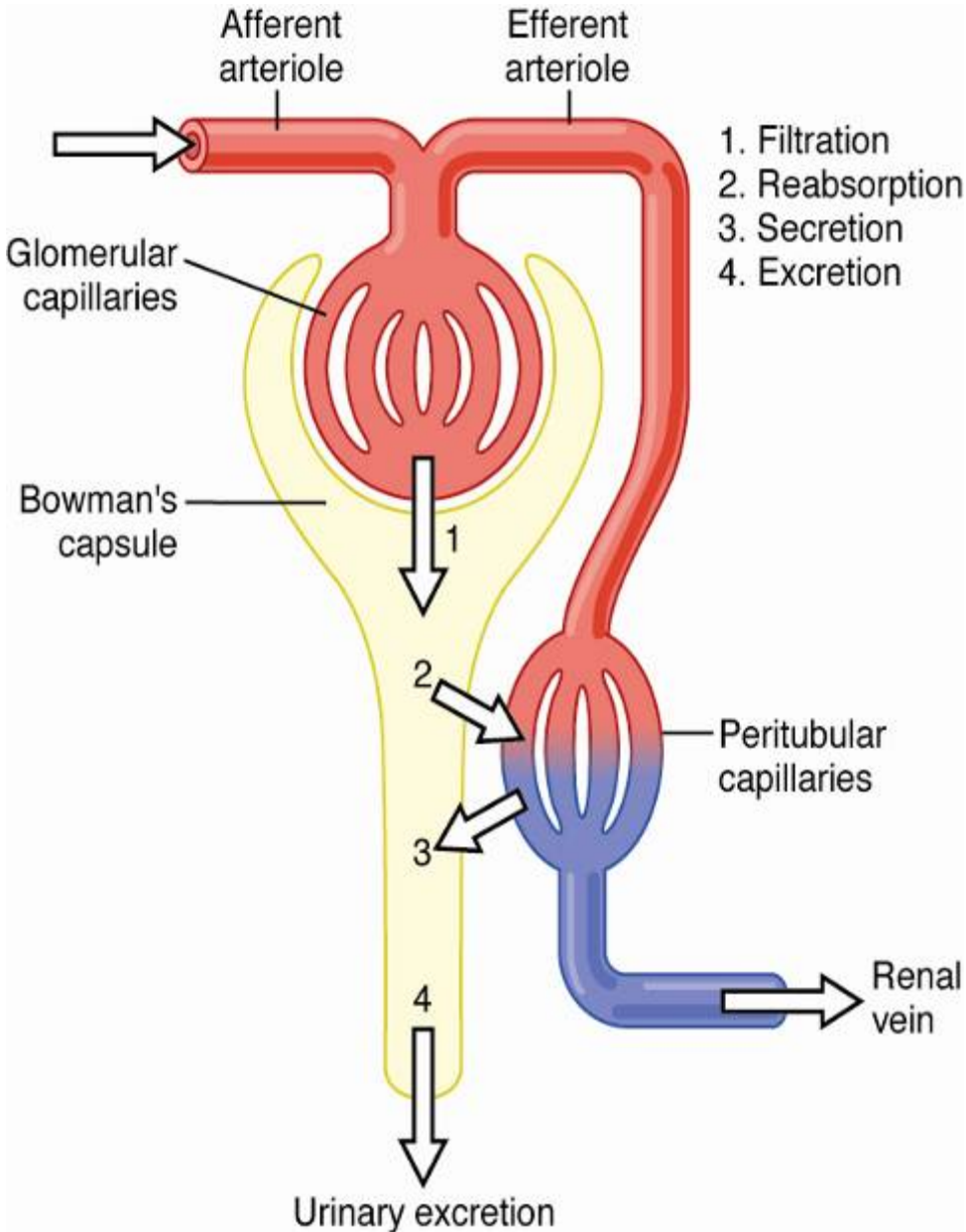


(a) Frontal section of right kidney



(b) Path of blood flow

Basic Mechanisms of Urine Formation



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

Figure 26-9

Basic Mechanisms of Urine Formation

- **Filtration :**

Passive, somewhat variable, not selective (except for proteins), averages 20% of renal plasma flow

- **Reabsorption :**

highly variable and selective

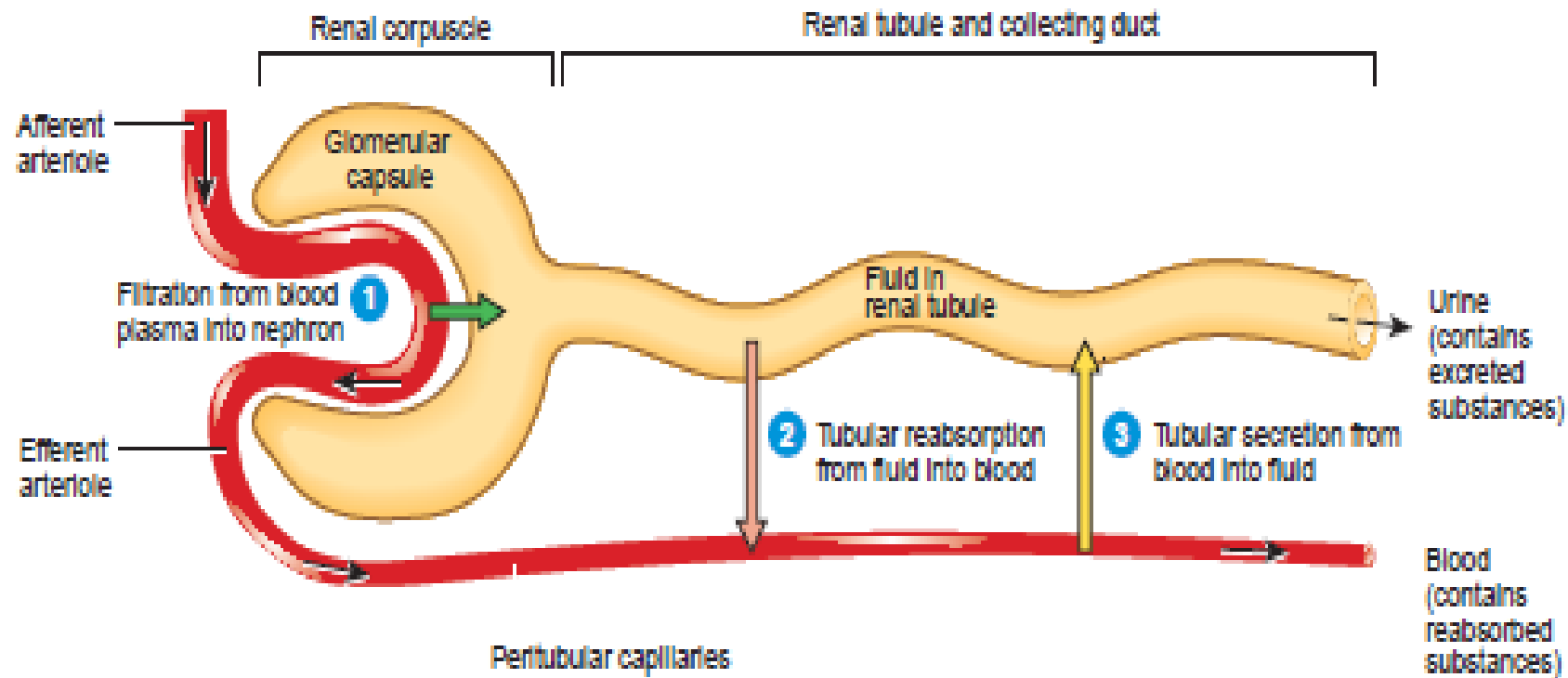
most electrolytes (e.g. Na^+ , K^+ , Cl^-) and nutritional substances (e.g. glucose) are almost completely reabsorbed; most waste products (e.g. urea)

poorly reabsorbed

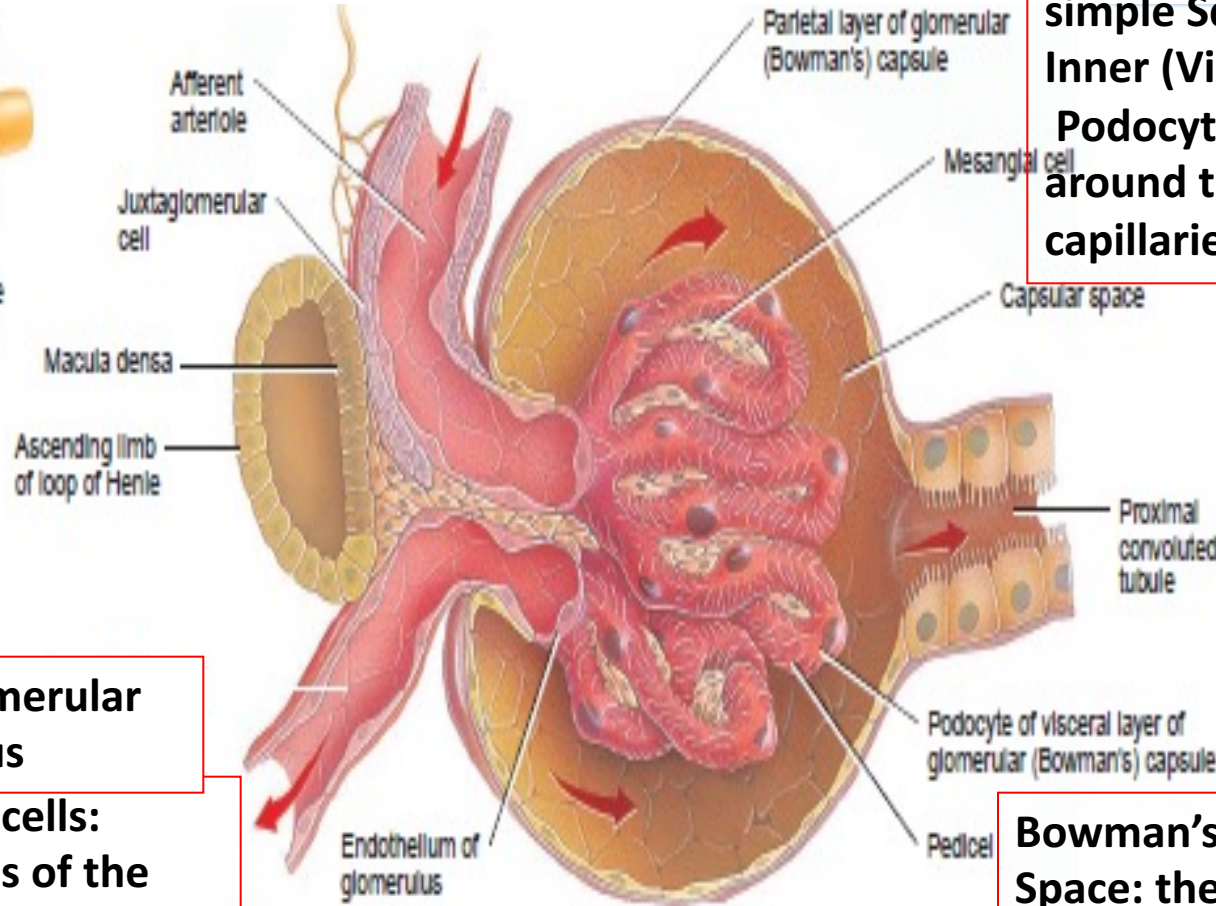
- **Secretion :** highly variable; important for rapidly excreting some

waste products (e.g. H^+), foreign substances (including drugs), and toxins

Nephron Structure and Function



Renal Corpuscle



Macula Densa: cells in the final part of the ascending loop of Henle

Juxtaglomerular Apparatus

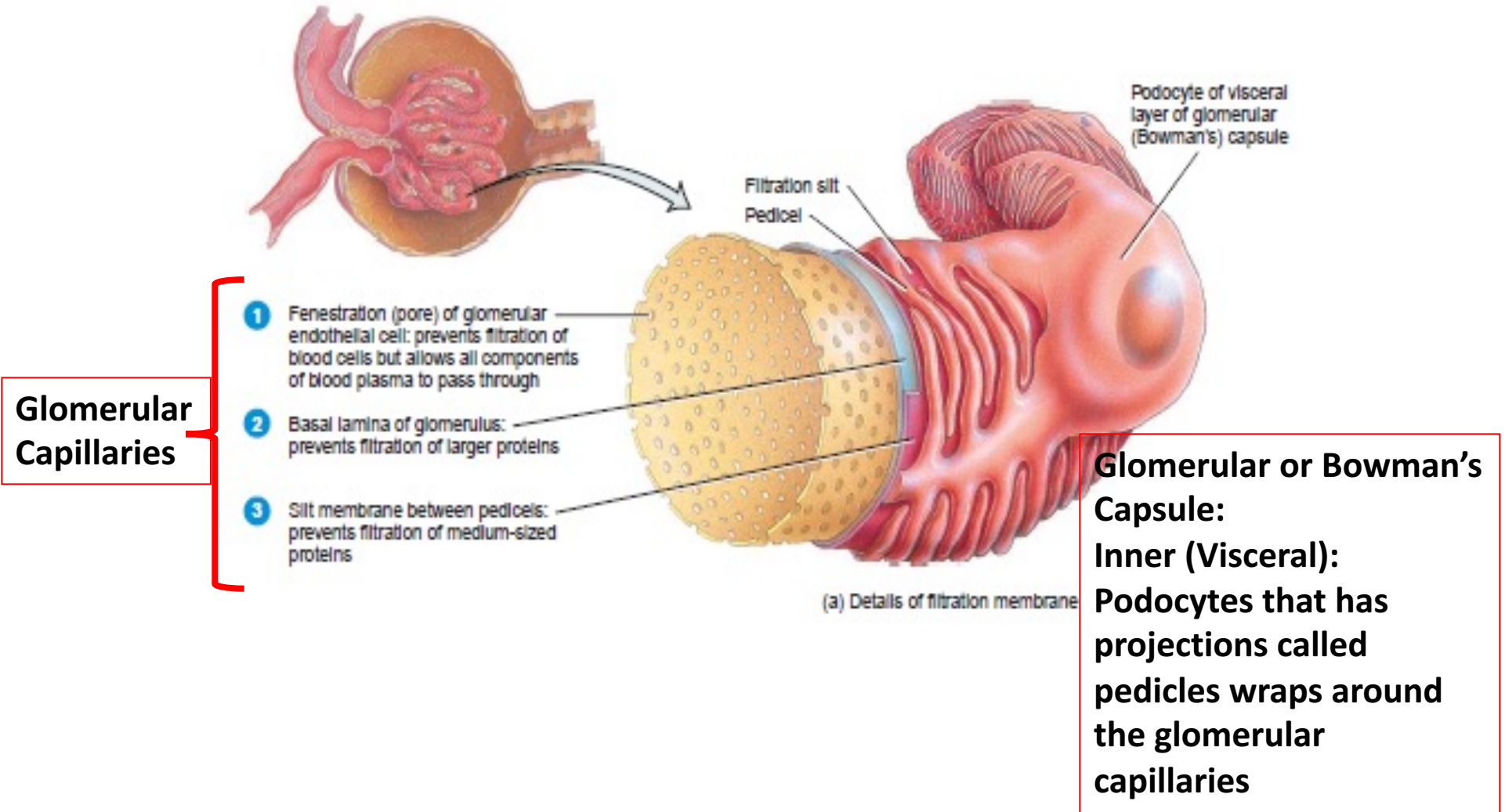
Juxtaglomerular cells: modified SM cells of the wall of afferent (or efferent) arterioles that are proximate to the Macula Densa.

Mesangial cells: are contractile cells lies in the clefts between afferent and efferent arterioles

Glomerular or Bowman's Capsule:
Outer: simple Squamous epith.
Inner (Visceral): Podocytes that wraps around the glomerular capillaries

Bowman's or Capsular Space: the space between the outer and inner layers of the capsule which is filled with the filtered fluids

Filtration Membrane



Glomerular capillary filtration barrier

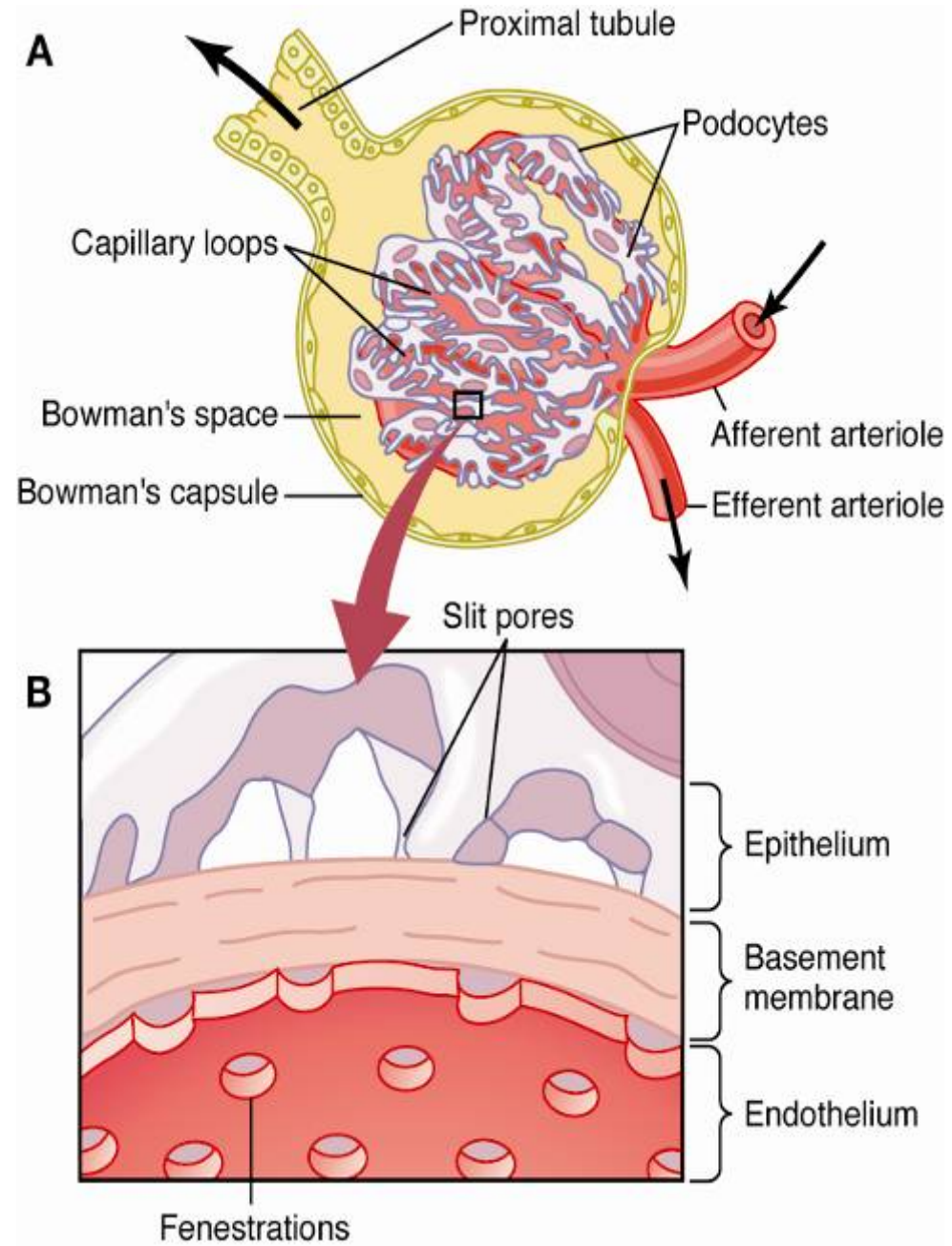


Figure 26-11

Renal Tubules and Collecting Ducts

- **Proximal Convoluted Tubule (PCT):** Simple cuboidal epithelial cells with brush borders.
- **Loop of Henle(LH):** Simple Squamous (thin), Cuboidal(Thick).
- **Distal Convoluted Tubule (DCT):** simple cuboidal.
- **Last part of DCT and Collecting Duct (CD):** Simple cuboidal consisting of:
 1. **Principal Cells:** contains receptors for ADH and Aldosterone.
 2. **Intercalated Cells :** Blood PH regulation