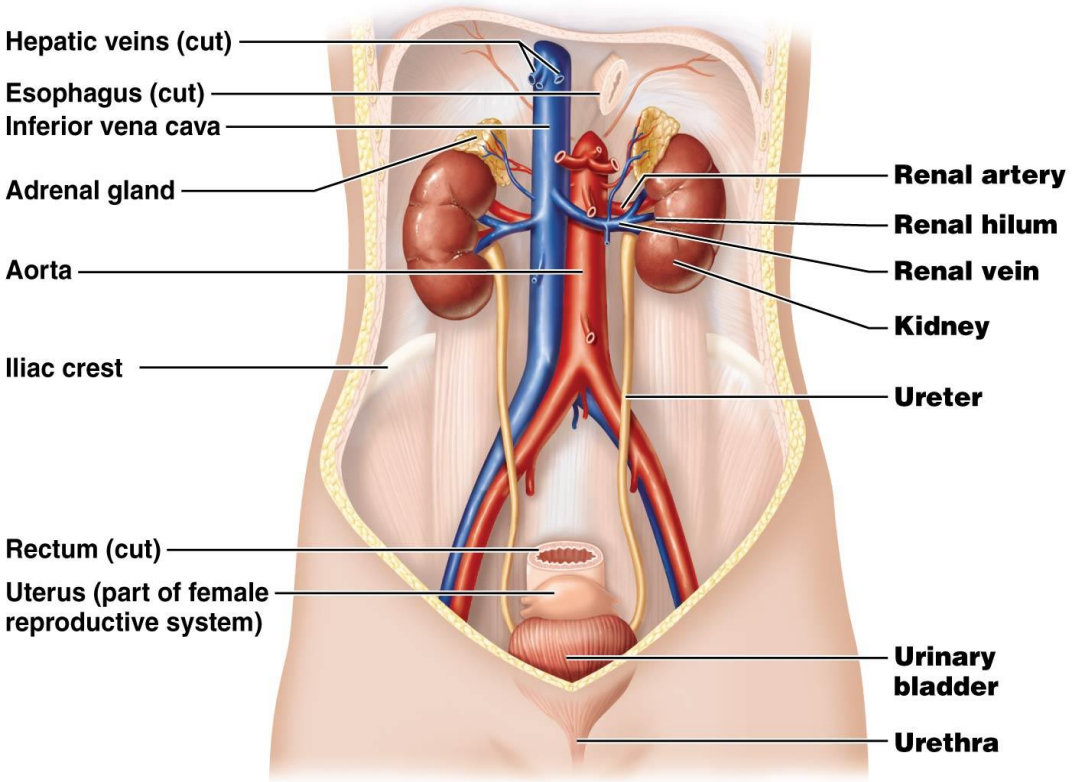


# The urinary System

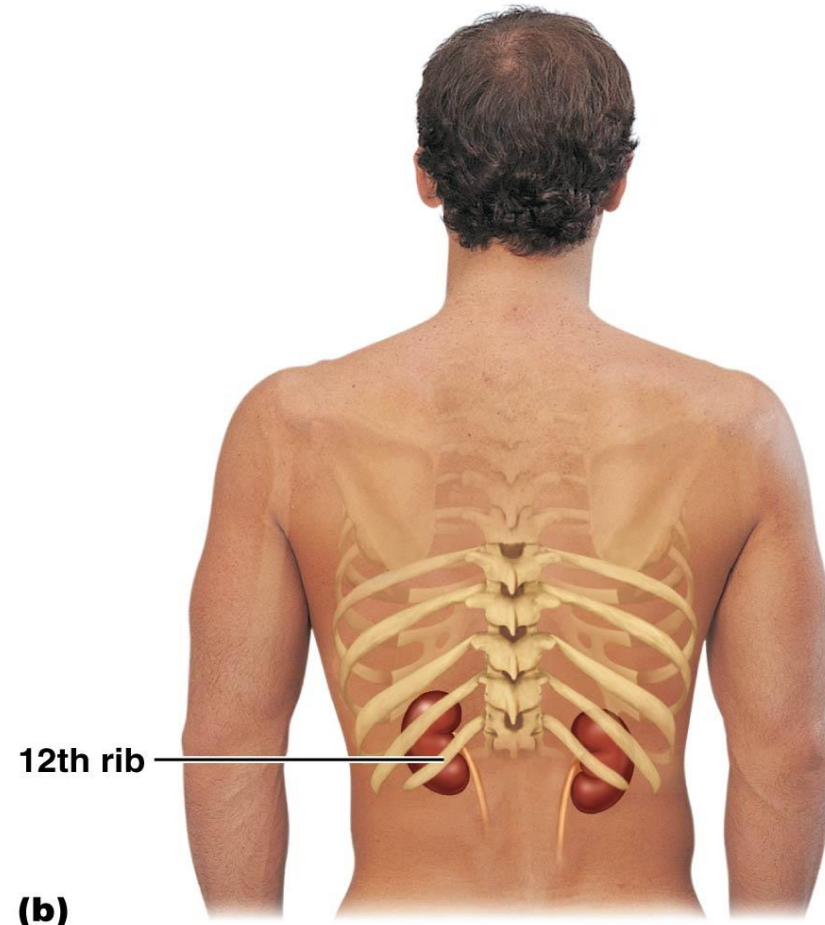
Dr. Ali Ebneshahidi

# Functions of the Urinary System

- **Excretion** – removal of waste material from the blood plasma and the disposal of this waste in the urine.
- **Elimination** – removal of waste from other organ systems;
  - from digestive system – undigested food, water, salt, ions, and drugs.
  - from respiratory system –  $\text{CO}_2$ ,  $\text{H}^+$ , water, toxins.
  - from skin – water,  $\text{NaCl}$ , nitrogenous wastes (urea, uric acid, ammonia, creatinine).
- **Water balance** -- kidney tubules regulate water reabsorption and urine concentration.
- regulation of **PH**, volume, and composition of body fluids.
- production of **Erythropoietin** for hematopoiesis, and **renin** for blood pressure regulation.



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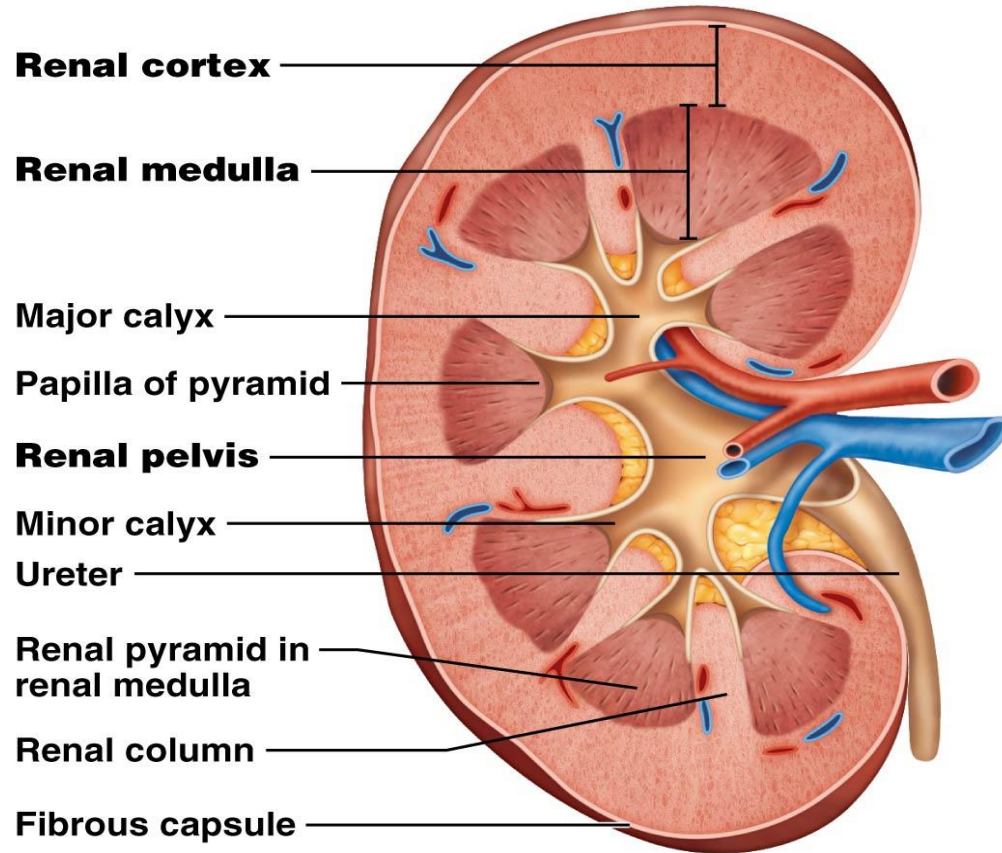


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# Anatomy of the Urinary System

Gross anatomy:

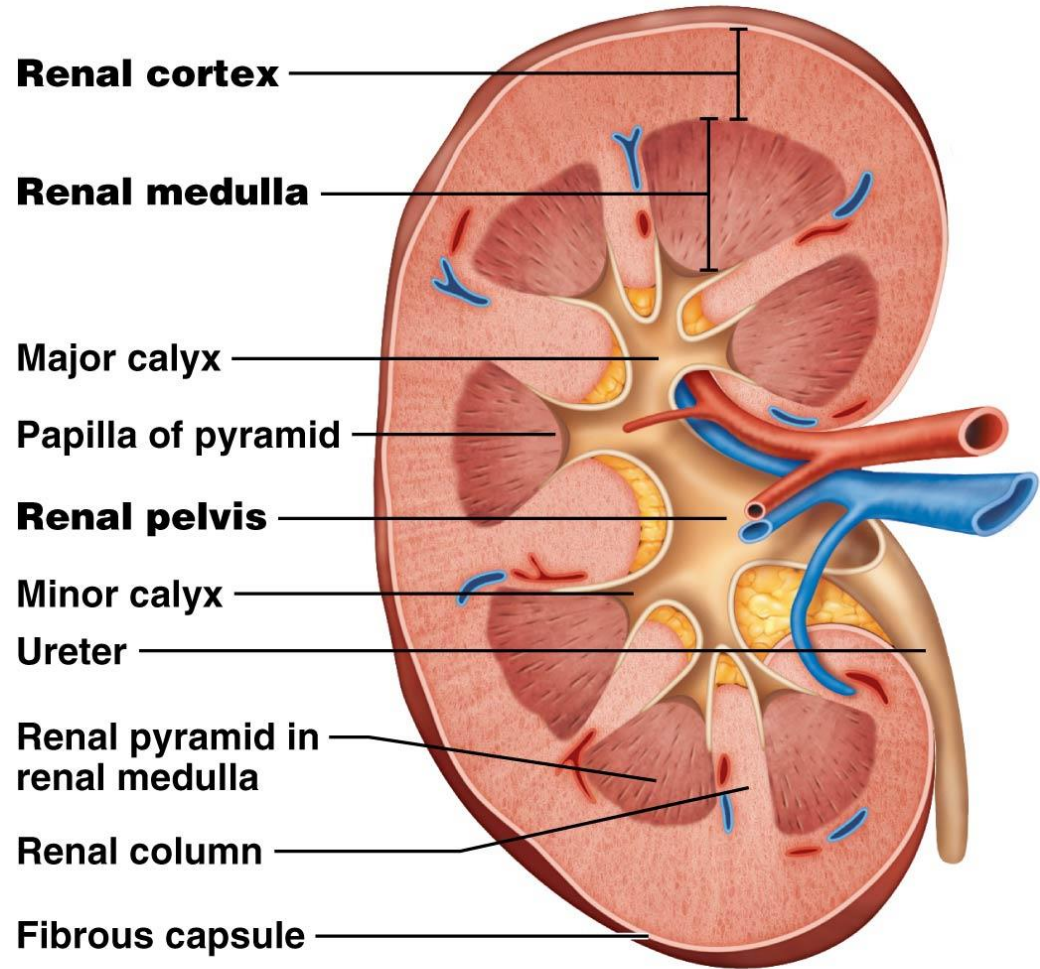
- **kidneys** – a pair of bean-shaped organs located retroperitoneally, responsible for blood filtering and urine formation.
- **Renal capsule** – a layer of fibrous connective tissue covering the kidneys.
- **Renal cortex** – outer region of the kidneys where most nephrons is located.
- **Renal medulla** – inner region of the kidneys where some nephrons is located, also where urine is collected to be excreted outward.



**(b) Diagrammatic view**

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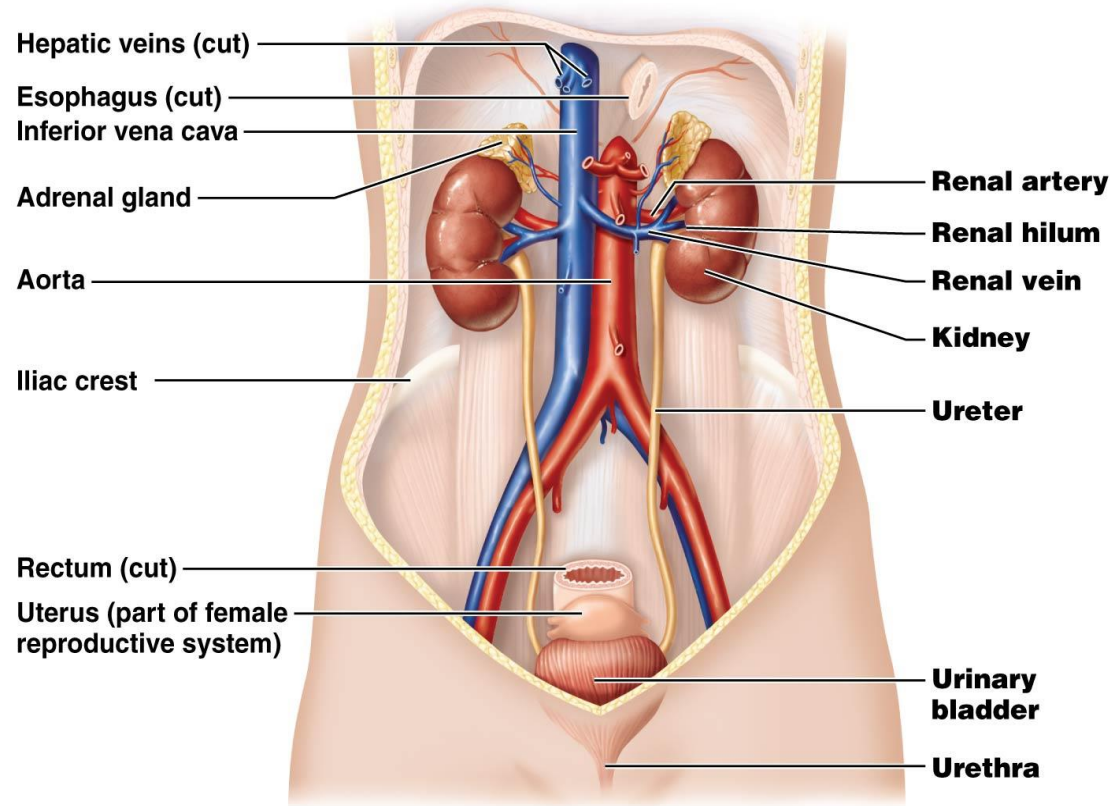
- **Renal calyx** – duct – like sections of renal medulla for collecting urine from nephrons and direct urine into renal pelvis.
- **Renal pyramid** – connective tissues in the renal medulla binding various structures together.
- **Renal pelvis** – central urine collecting area of renal medulla.
- **Hilum** (hilus) – concave notch of kidneys where renal artery, renal vein, ureter, nerves, and lymphatic vessels converge.



**(b) Diagrammatic view**

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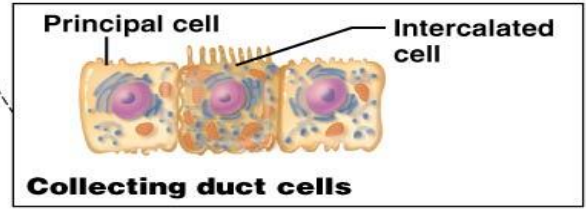
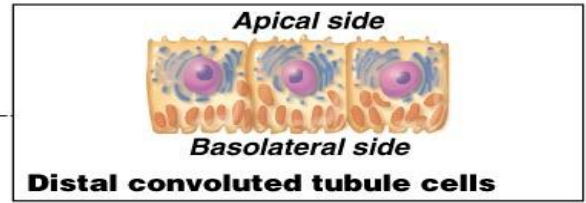
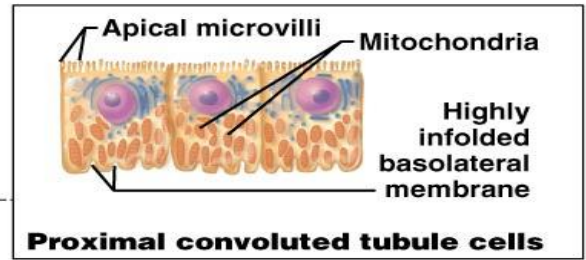
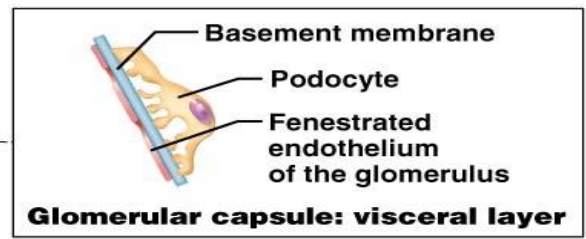
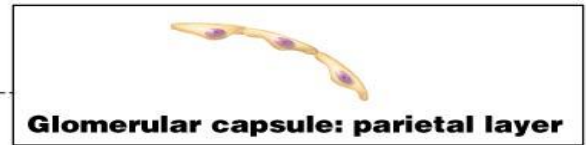
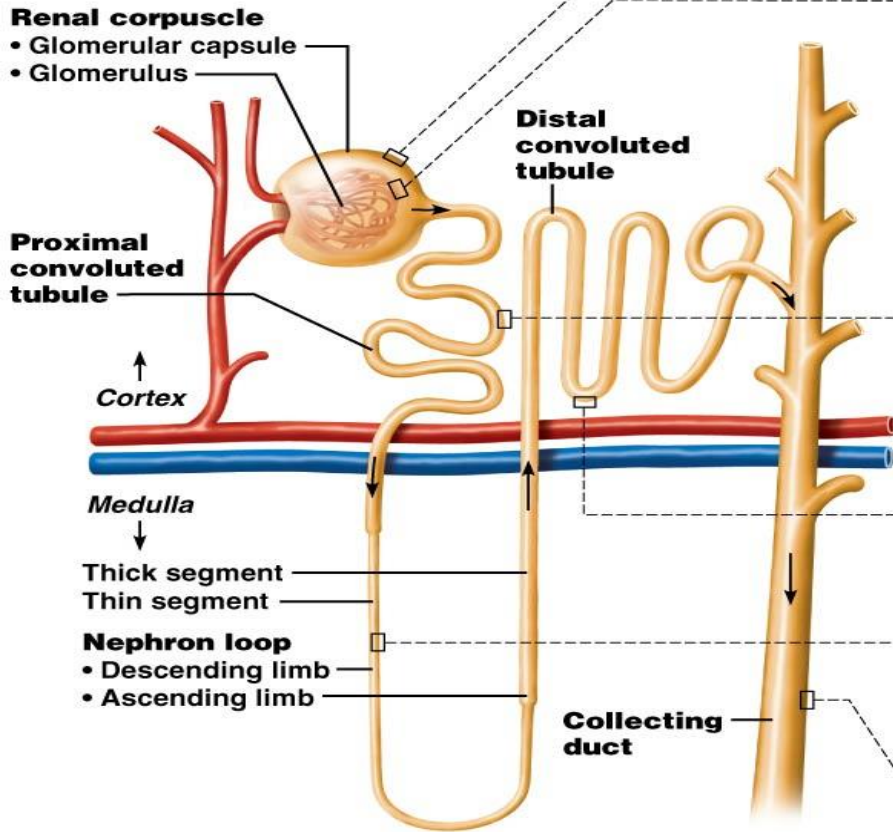
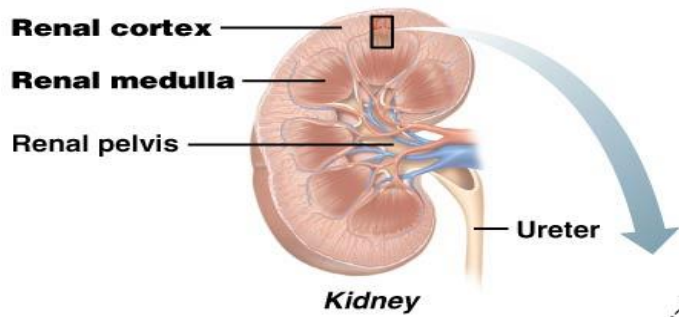
- **Ureter** – a tubule that transport urine (mainly by peristalsis) from the kidney to the urinary bladder.
- **Urinary bladder** – a spherical storage organ that contains up to 400 ml of urine.
- **Urethra** – a tubule that excretes urine out of the urinary bladder to the outside, through the urethral orifice.



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## Microscopic anatomy:

- each kidney consists of about **1** million basic functional units called nephrons where blood filtering and urine formation occur.
- each nephron is composed of the following parts –
- **afferent arteriole** → **glomerulus** → **Bowman's capsule** → **proximal convoluted tubule (PCT)** → descending limb of **loop of Henle** → ascending limb of loop of henle → **distal convoluted tubule(DCT)** → **collecting duct** (not a part of nephron).
- molecules in the blood that will be transformed to become part of urine travel through the above structures to be processed (some of these molecules will be reabsorbed), while molecules that will be retained and reabsorbed back to the blood will come out of the bowman's capsule, and go into **efferent arteriole** and the **peritubular capillaries**.



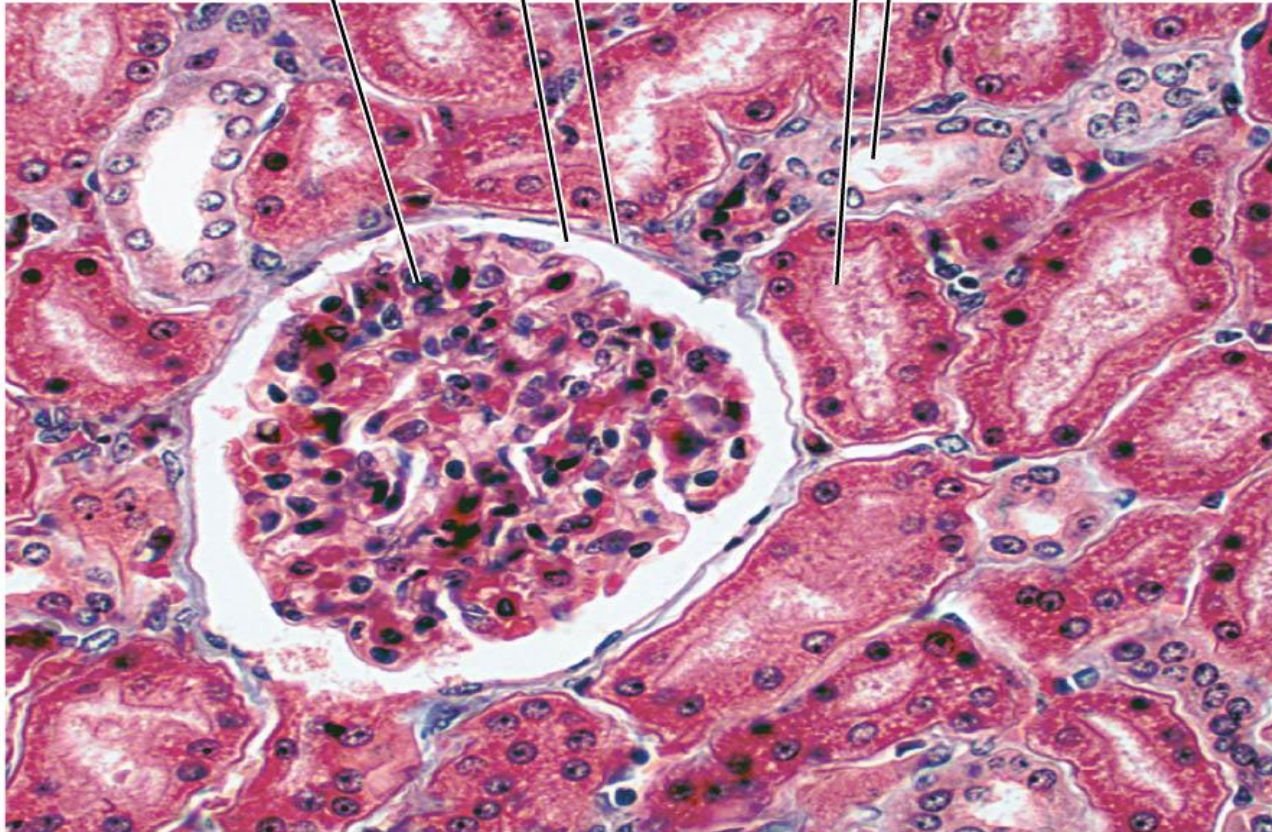


### **Renal corpuscle**

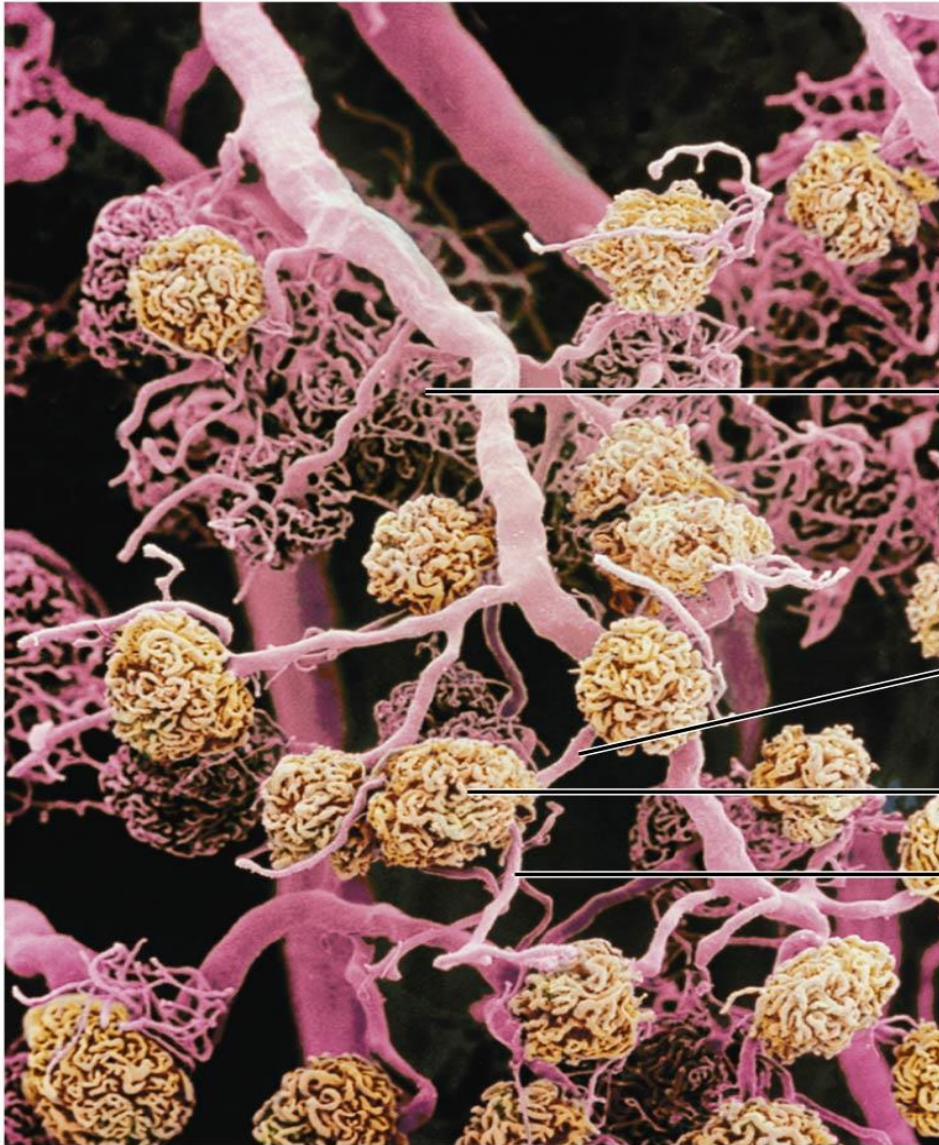
- Squamous epithelium of parietal layer of glomerular capsule
- Glomerular capsular space
- Glomerulus

**Proximal convoluted tubule** (fuzzy lumen due to long microvilli)

**Distal convoluted tubule** (clear lumen)



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**Peritubular  
capillary bed**

**Afferent  
arteriole**

**Glomerulus**

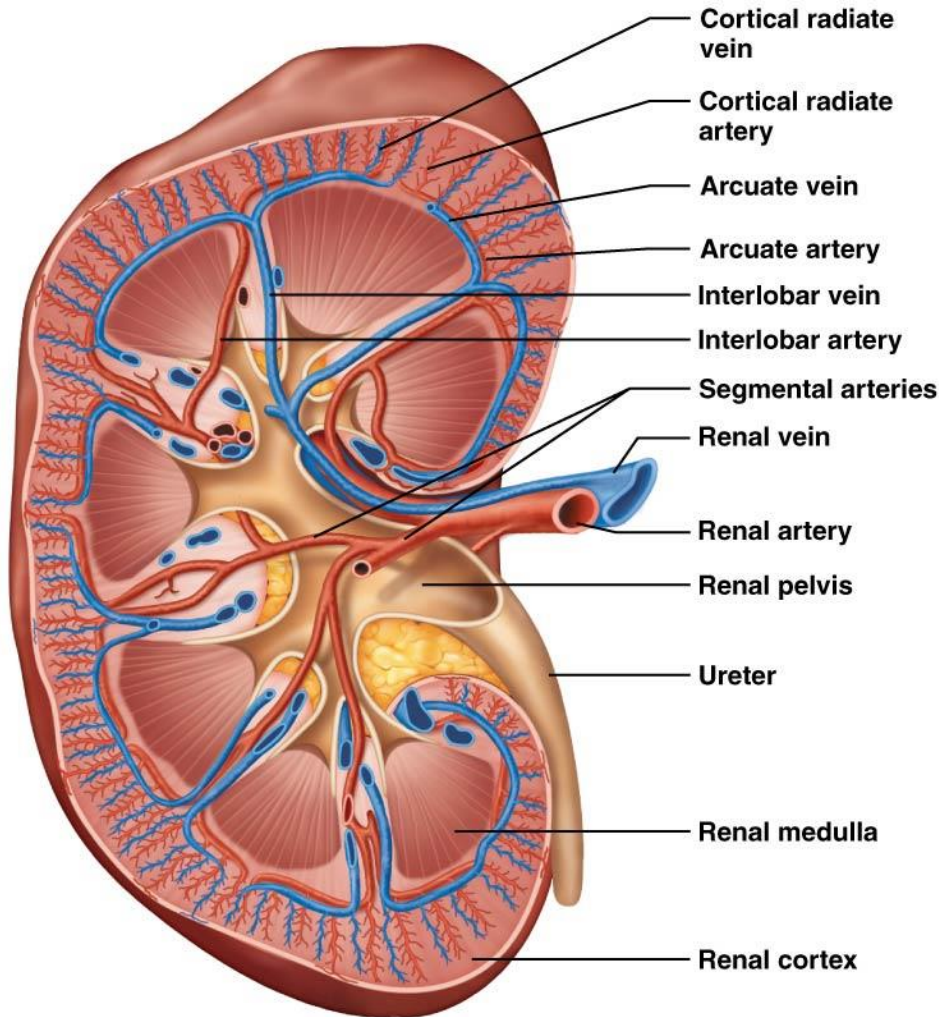
**Efferent  
arteriole**

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# Urine Formation

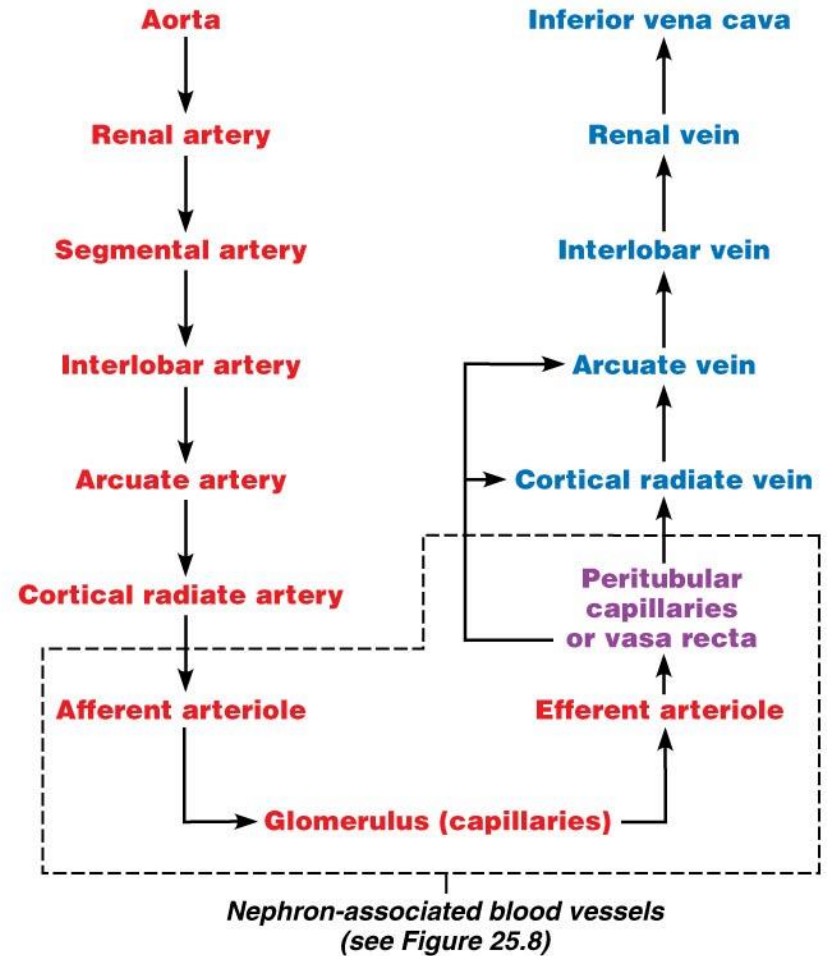
1. during rest, about 15-30% of cardiac output (CO) enters the kidneys.
2. circulation through the kidneys (blood cells and plasma proteins follow the following pathway, while smaller substances will be filtered into renal tubules and are mostly reabsorbed).  
aorta → renal artery → interlobular arteries → afferent arterioles → glomeruli → efferent arterioles → peritubular capillaries → interlobular veins → renal vein → inferior vena cava.
3. 80% of all nephrons is located in the renal cortex and called **cortical nephrons** which contain shorter loops of henle (for less efficient water reabsorption), while the remaining 20% of nephrons is located between renal cortex and medulla and called **juxtamedullary nephrons** which contain longer loops of henle (for efficient water reabsorption).

# Renal Vasculature Pathway



**(a) Frontal section illustrating major blood vessels**

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**(b) Path of blood flow through renal blood vessels**

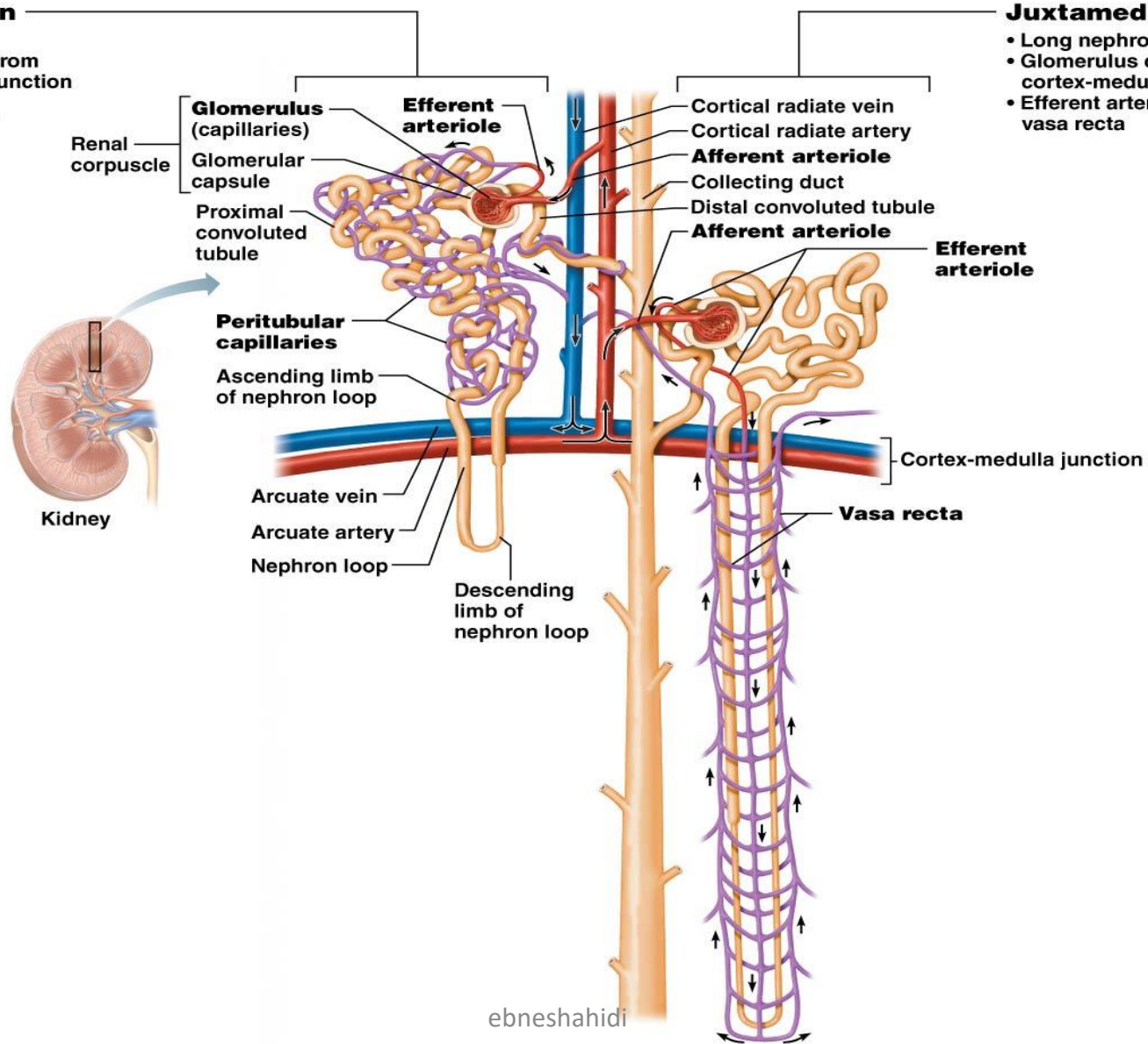
- **Vasa recta**: efferent arterioles of the juxtamedullary nephron form a unique bundle of straight vessels, called the vasa recta.

**Cortical nephron**

- Short nephron loop
- Glomerulus further from the cortex-medulla junction
- Efferent arteriole supplies peritubular capillaries

**Juxtamedullary nephron**

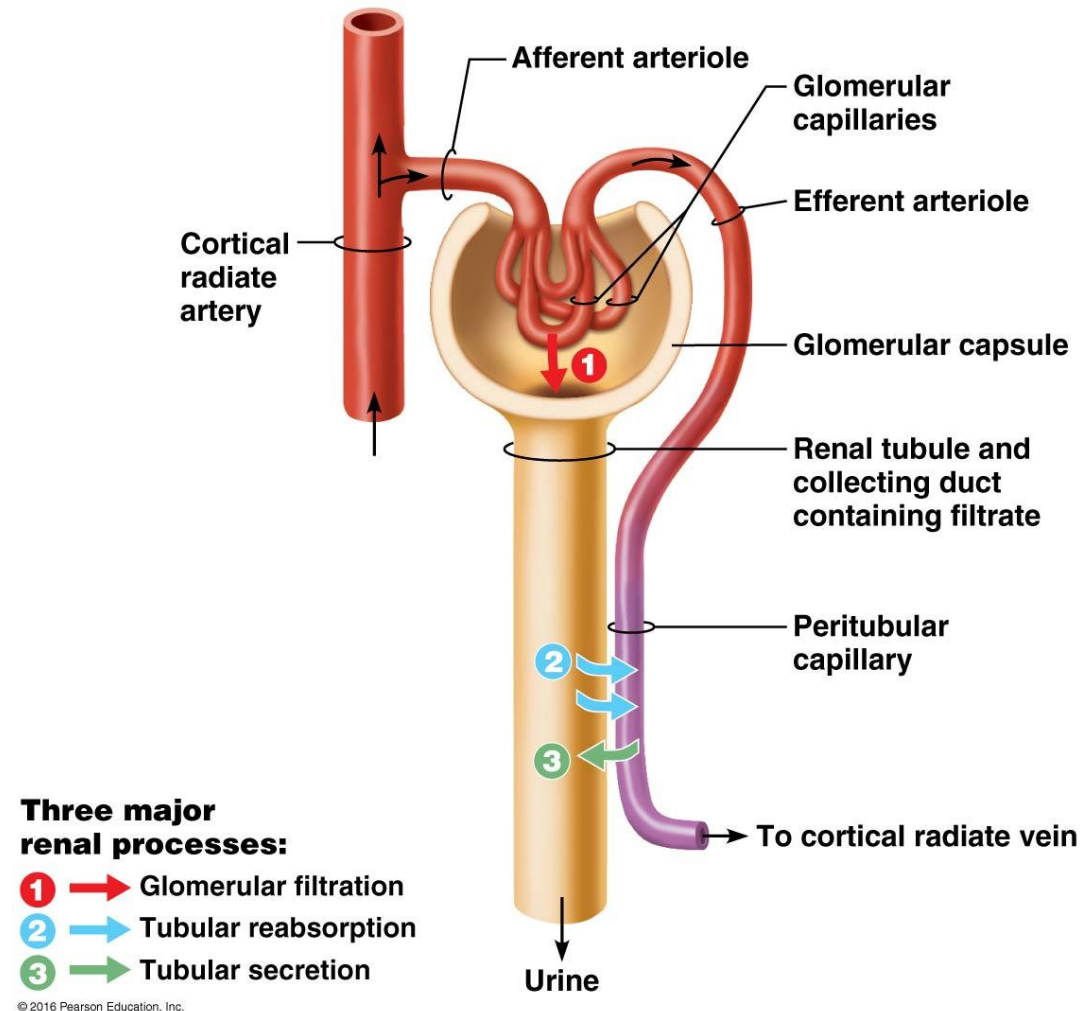
- Long nephron loop
- Glomerulus closer to the cortex-medulla junction
- Efferent arteriole supplies vasa recta



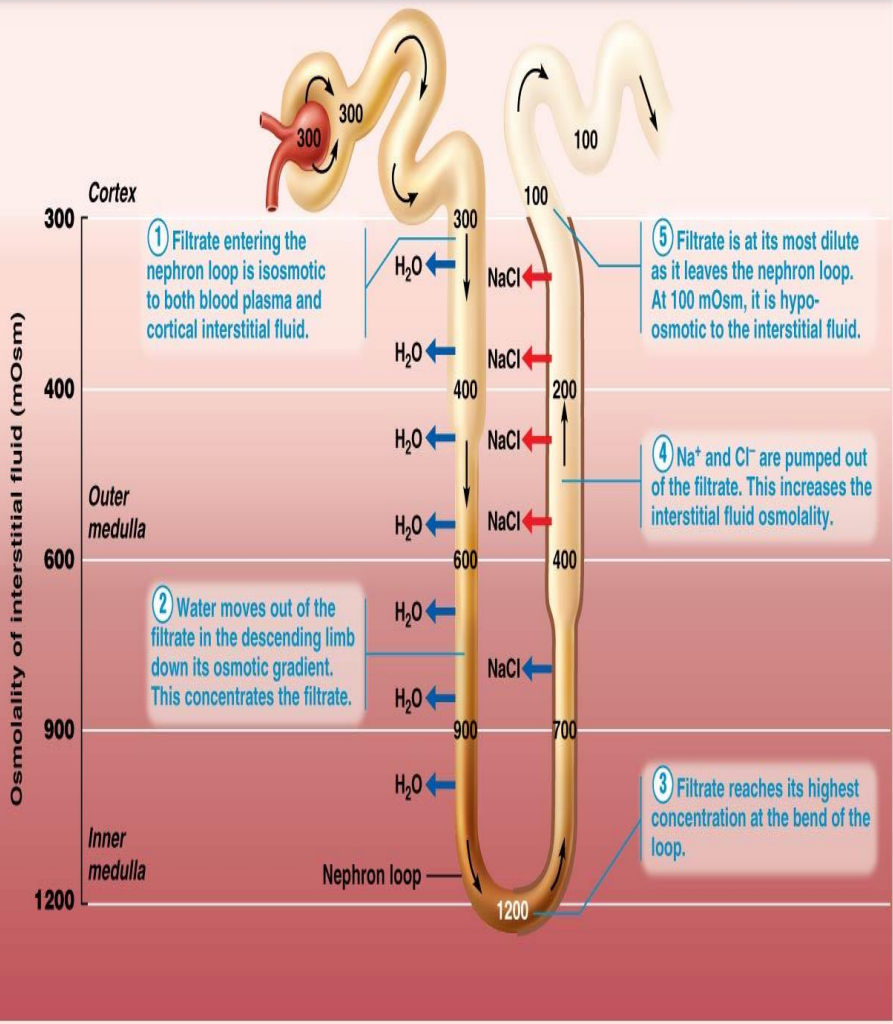
ebneshahidi

4. urine formation involves 4 processes:

- **filtration** – small molecules are filtered from glomerulus to bowman's capsule.
- **reabsorption** – nutrient molecules are transported from PCT and DCT to peritubular capillaries.
- **concentration** – water is reabsorbed from descending limb of loop of henle and from collecting duct into peritubular capillaries.
- **secretion** – waste or harmful substances are transported from peritubular capillaries to PCT and DCT.

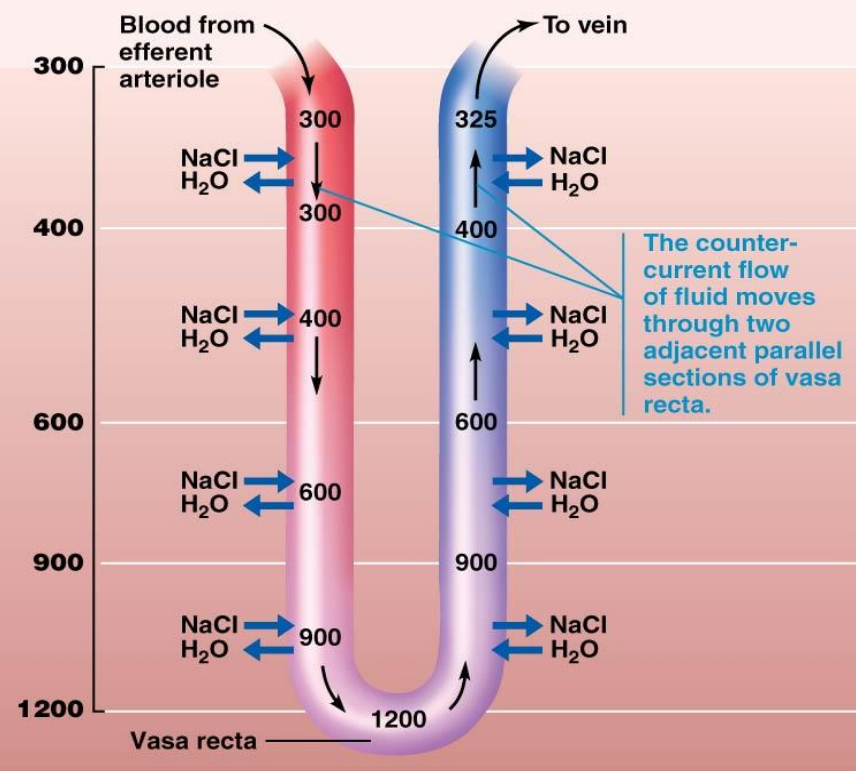


**As water and solutes are reabsorbed, the loop first concentrates the filtrate, then dilutes it.**



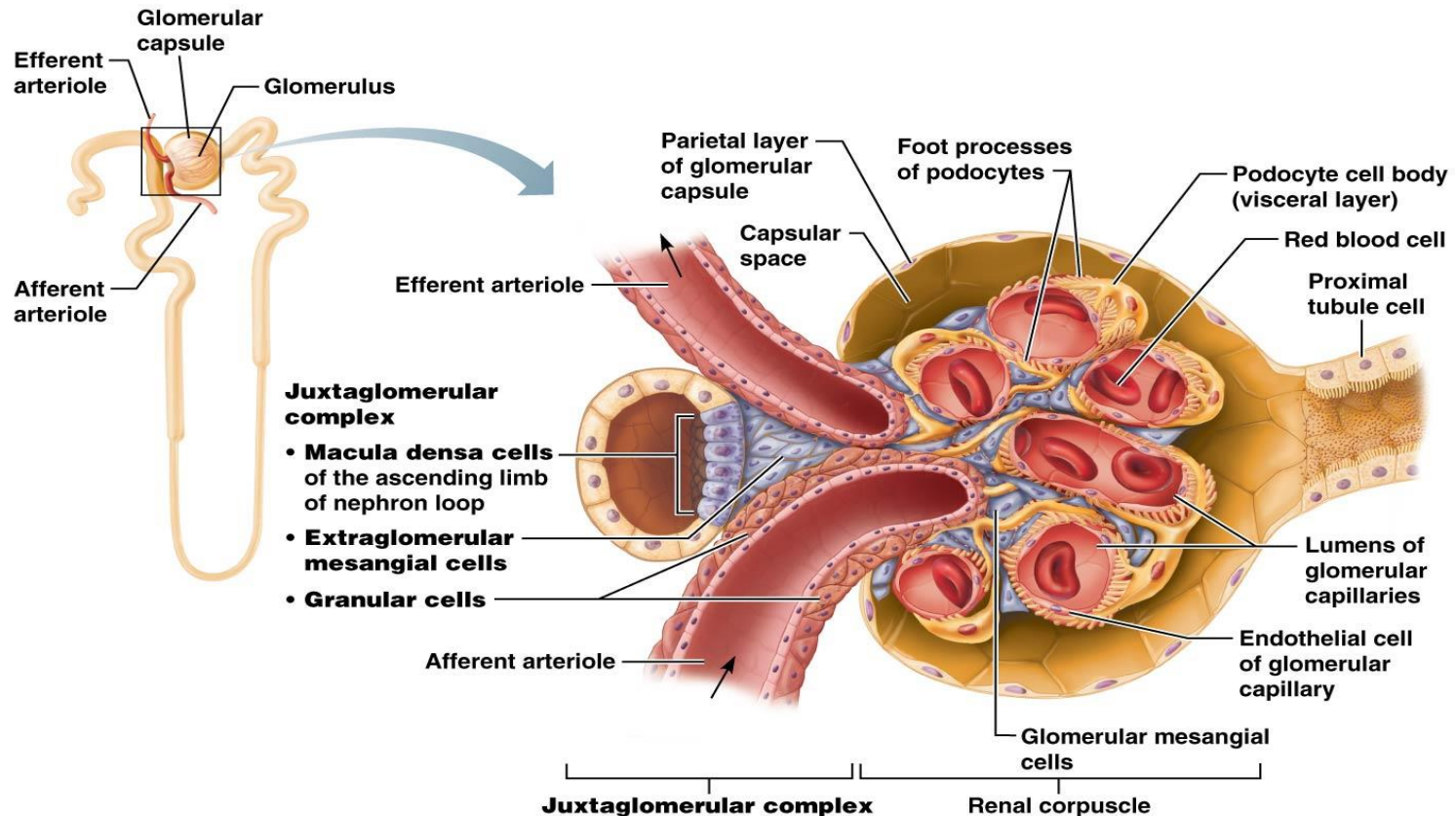
**Vasa recta preserve the gradient.**

- **The vasa recta are highly permeable to water and solutes.**
- **Countercurrent exchanges occur between each section of the vasa recta and its surrounding fluid. As a result:**
  - The blood within the vasa recta remains nearly isosmotic to the surrounding fluid.
  - The vasa recta are able to reabsorb water and solutes into the general circulation without undoing the osmotic gradient created by the countercurrent multiplier.



# Juxtaglomerular Apparatus (JGA)

- Macula densa – epithelial cells of the Ascending limb & distal convoluted tubule that are densely packed. These cells are chemo and osmoreceptors that detect changes in solute concentration and blood pressure.
- Juxtaglomerular cells (Granular cells) – large cells in the wall of the afferent arterioles that secrete renin and act as mechanoreceptor. **Renin** plays an important role in control of **blood pressure**.





# Composition of Urine

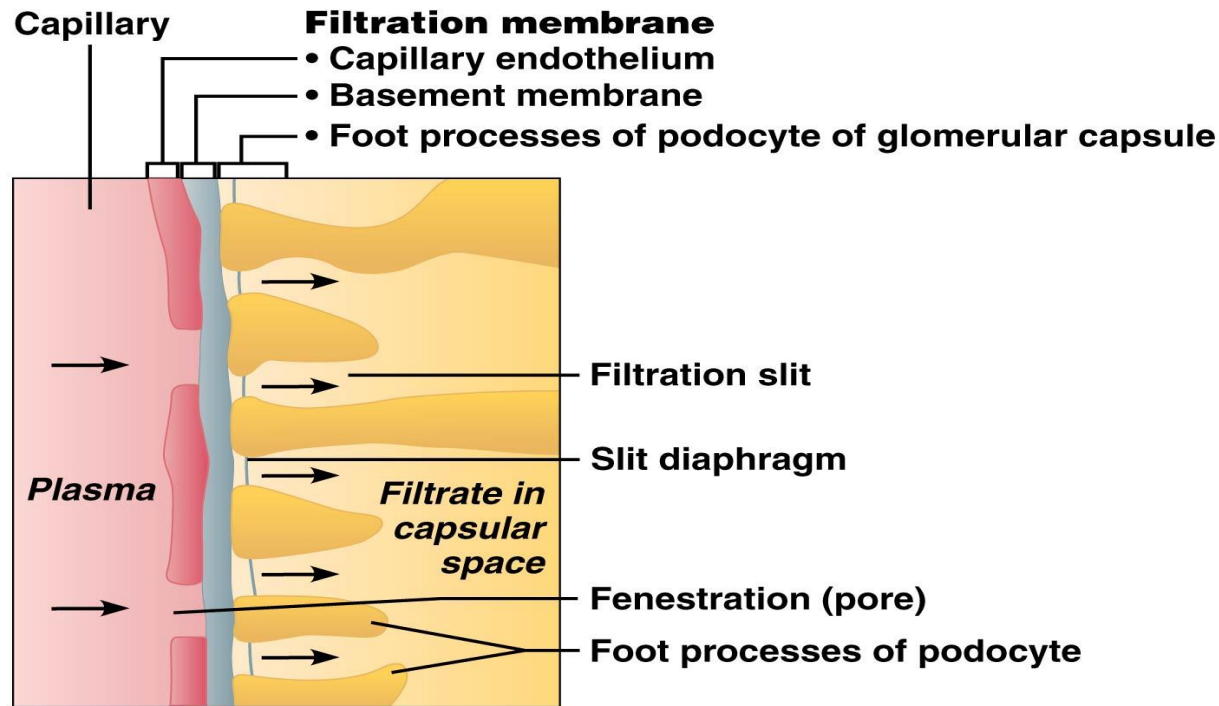
- **transparency** is clear, indicating the lack of large solutes such as plasma proteins or blood cells [can be influenced by bacterial metabolism in older urine samples].
- **Color** is from light yellow to amber, due to urochrome pigments as byproduct of bile metabolism [can be influenced by food, menstrual bleeding, and metabolic products].
- **Odor** is from aromatic to slightly ammonia – like, due to the nitrogenous wastes in urine [can be influenced by disorders such as diabetes, or by food such as garlic, and by drugs].
- **pH** is from 4.6 to 8.0 with an average of 6.0, due to  $H^+$  in the urine [strongly influenced by diet where protein cause acidic urine, and vegetables and wheat cause alkaline urine].
- **Specific gravity** (a measurement of dissolved solutes in a solution) is from 1.001 to 1.035, due to the 5% solute composition in normal urine.

– **Volume** is 1-2 liters per day (about 1% of filtration input) [can be influenced by body activities, water intake, hormonal regulation, or disorders such as diabetes].

• **chemical composition of urine:**

- normal urine is 95% water and 5% solutes.

- most solutes are derived from cellular metabolism, and they include urea, uric acid, creatinine, ketone bodies, salts, ions, excessive vitamins, and drugs.



**(d) Three layers of the filtration membrane**

# Abnormal Constituents of Urine

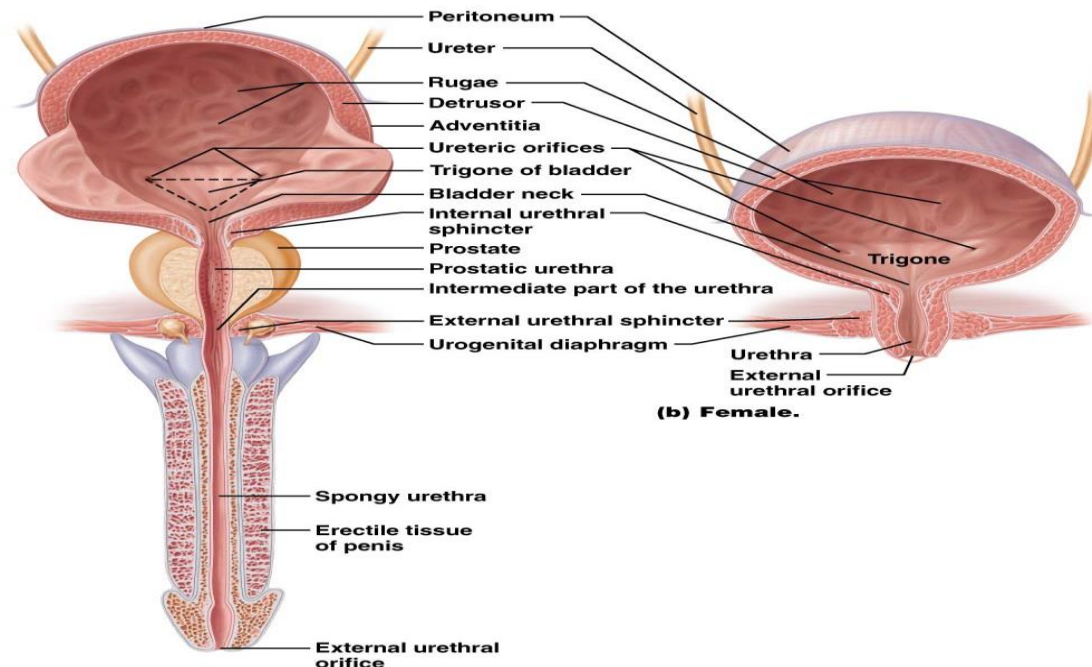
- **albumin** – a large plasma protein that should not be filtered out of glomerulus; when it is present, it is called **albuminuria** which may be due to kidney infection called glomerulonephritis.
- **glucose** – a nutrient molecules that should have been reabsorbed (in the case of high carbohydrate diets, trace amount of glucose may be found in urine); when is present, it is called **glucosuria** which may be due to insulin – related problems in a disease called diabetes mellitus.
- **blood or erythrocytes** – any blood cell should not be filtered out of glomerulus or be present in the urine (except in menstruation – related bleeding); when it is present, it is called **Hematuria** which may be caused by glomerulonephritis, hemolytic anemia, or urinary tract in infections (UTI).

- **hemoglobin** – pigment protein that normally should be enclosed in erythrocytes and not filtered out of glomerulus; when it is present, it is called **hemoglobinuria** which may indicate hemolytic anemia.
- **leukocytes** – large white blood cells that should not be present in urine (except in UTI where leukocytes are present to fight the infection); when it is present, it is called **Pyuria** which may be caused by glomerulonephritis, UTI, or even strenuous exercise.
- **ketones** – byproduct of metabolism that may occur in trace amounts, but not large quantities in the urine; when it is present, it is called **Ketonuria** which may indicate certain infections in the urinary system.
- **Bilirubin** – a bile pigment that is normally recycled in lipid metabolism; when it is present, it is called **bilirubinuria** which may be due to abnormal lipid metabolism, or certain infections in the urinary system.

# Micturition

- elimination of urine from the urinary system to the outside.
- pathway of waste molecules:  
afferent arteriole → glomerulus → Bowman's capsule → proximal convoluted tubule → loop of henle → distal convoluted tubule → collecting duct → renal calyx → renal pelvis → ureter → urinary bladder → urethra → urethral orifice.
- middle layer of ureter wall is made of smooth muscle, which performs **peristalsis** under involuntary control, to push urine from the kidney to urinary bladder.
- urinary bladder contains elastic tissues in its walls and normally holds 200-400 ml of urine, or maximally up to 600 ml.
- micturition involves the contraction of **detrusor muscles** that surround the urinary bladder and the relaxation of **external urethral sphincter**.

- At the bladder-urethral junction a thickening of the detrusor smooth muscle forms the **internal urethral sphincter** which keeps urethra closed when urine is not being passed and prevents leaking between voiding.
- Parasympathetic nerves stimulate contraction of detrusor muscles, forcing urine into urethra.
- Voluntary relaxation of external urethral sphincter (which is made up of skeletal muscles) allows urine to flow outside.



**(a) Male.** The long male urethra has three regions: prostatic, intermediate, and spongy.

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# Clinical Terms

- **Cystectomy:** surgical removal of the urinary bladder.
- **Dysuria:** painful or difficult urination.
- **Hematuria:** blood in the urine.
- **Nephrectomy:** surgical removal of a kidney.
- **Acute glomerulonephritis:** inflammation of the glomeruli.
- **Uremia:** condition in which substances ordinarily excreted in the urine accumulates in the blood.
- **Incontinence:** inability to control urination.
- **Urinalysis:** analysis of urine to diagnose health or disease (to detect protein, glucose, blood or pus).
- **Urologist:** physician who specializes in diseases of the urinary structures in both male and female.