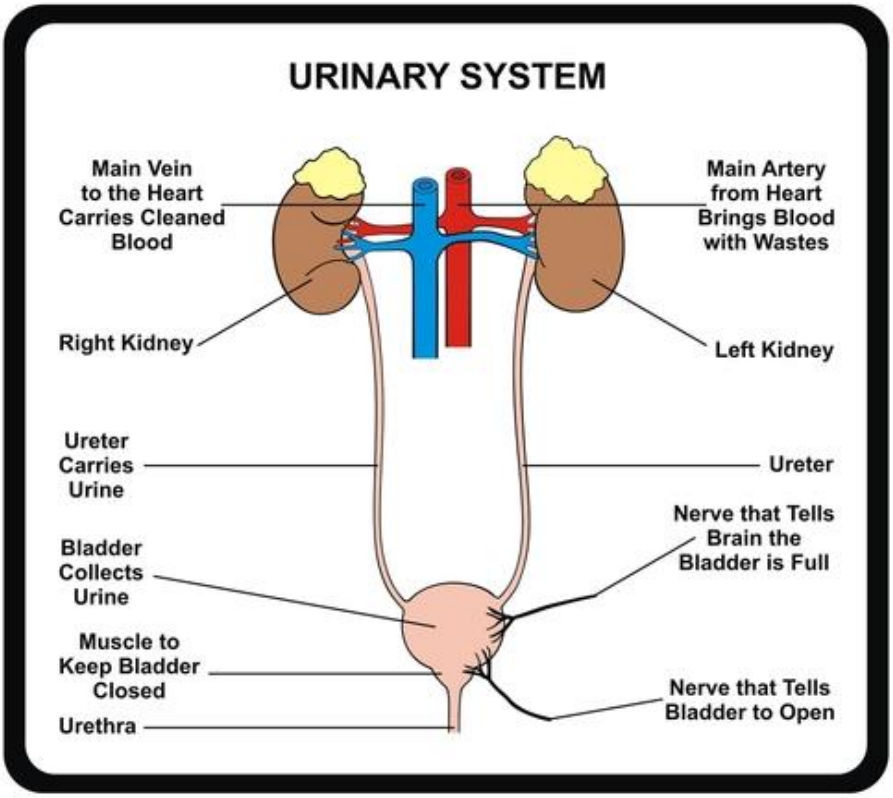
Structure of the Urinary System

The two kidneys lie in the back of the abdominal wall but not in the abdominal cavity. They are retroperitoneal, meaning they are just behind the peritoneum (the lining of this cavity). The urinary system composed from the 2 **kidneys**, 2 **ureters** , **urinary bladder,** and **urethra**.



Urinary system functions:

1. Regulation of water and inorganic-ion balance

2. Removal of metabolic waste products from the blood and their excretion in the urine

3. Removal of foreign chemicals from the blood and their excretion in the urine

4. Gluconeogenesis

5. Secretion of hormones:

a. Erythropoietin, which controls erythrocyte production

b. Renin, which controls formation of angiotensin, which influences blood pressure and sodium balance

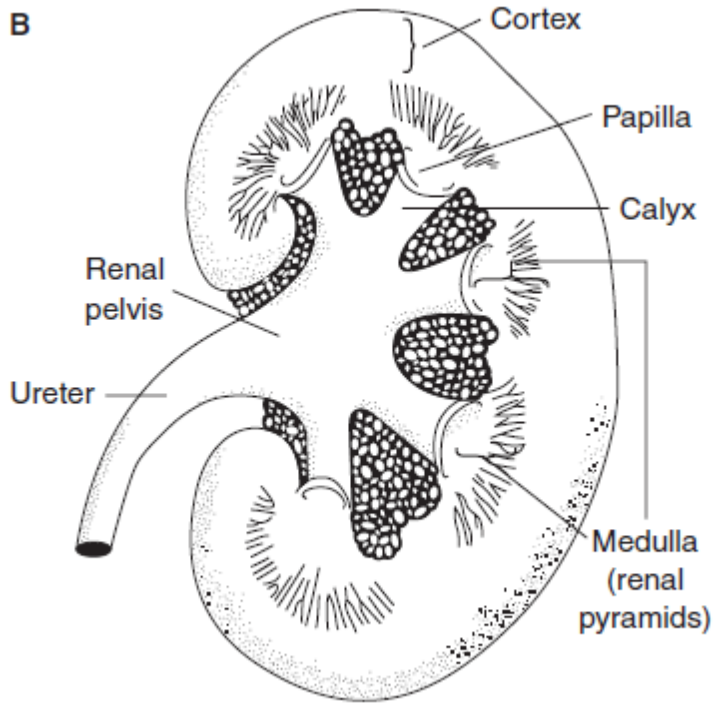
c. 1,25-dihydroxyvitamin D3, which influences calcium balance

6. Regulation of acid-base balance.

Structure of the kidney:

The 2 kidneys lie outside the peritoneal cavity close to the posterior abdominal wall, one on each side of the vertebral column. Each of the 2 kidneys is a bean-shaped structure. The rounded, outer convex surface of each kidney faces the side of the body, and the indented surface, called the ***hilum***, is medial. Each hilum is penetrated by a **renal artery**, **renal vein**, **nerves**, and a **ureter**.

Each kidney contains approximately 1 million nephrons. The nephron is functional unit of kidney, The nephron is composed of corpuscle and tubules. The corpuscle located in the outer layer of kidney which called cortex, therefor, the cortex appears granular (in longitudinal section). The tubules located in the inner layer of kidney which called medulla, medulla have radiated appearance as result presence of tubules.



Structure of the Nephron: The nephron composed of two parts

1-The Renal Corpuscle

The renal corpuscle consists of a compact tuft of interconnected capillary loops, that called ***glomerulus*** or **glomerular capillaries**, surrounded by a balloon-like hollow capsule called **Bowman's capsule**. Blood enters and leaves Bowman's capsule through arterioles that penetrate the surface of the capsule at the vascular pole, the entered arteriole called **afferent** arteriole and exited arteriole called **efferent** arteriole. A fluid-filled space (the urinary space or Bowman's space) exists within the capsule, and it is into this space that fluid filters. Opposite the vascular pole, Bowman's

capsule has an opening that leads into the first portion of the tubule. The main function of corpuscle is glomerular **filtration**.

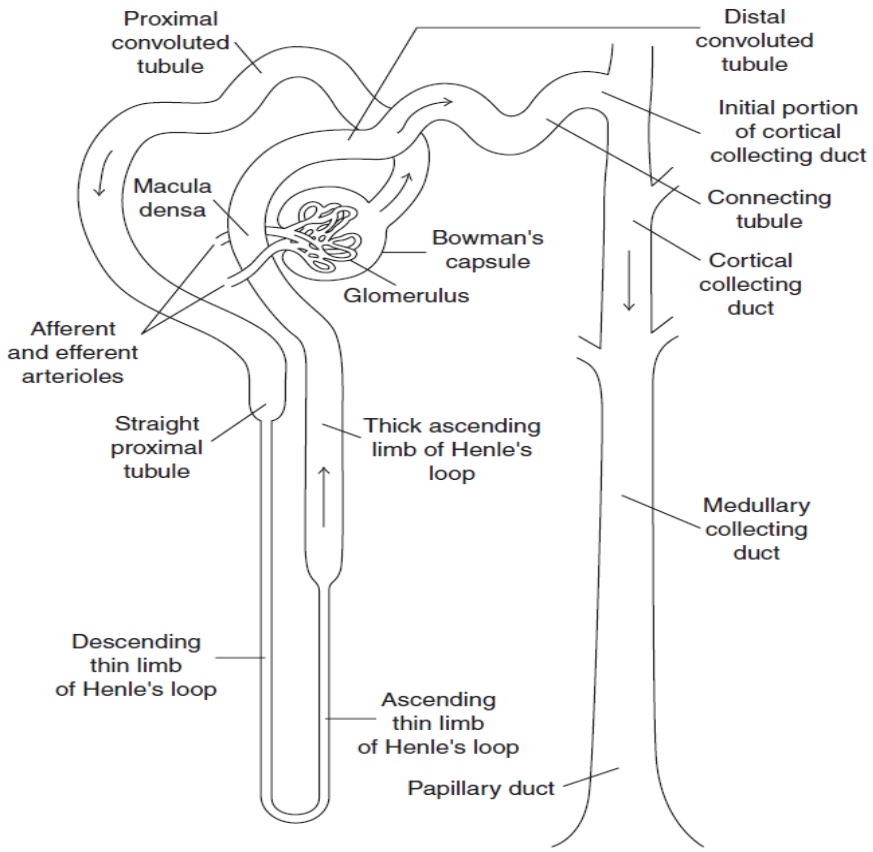
2- The Renal Tubules

It is long tubule extend from renal corpuscle to collecting duct which is empty urine in to kidney pelvis.

The main function of renal tubules is transport of formed urine from corpuscle to collecting duct to eliminated out of kidney, also applied some processes on formed urine when pass through tubule (**reabsorption** and **secretion**).

The tubules wall have on layer of epithelial cells based on basement membrane layer. The renal tubules composed of three major parts:

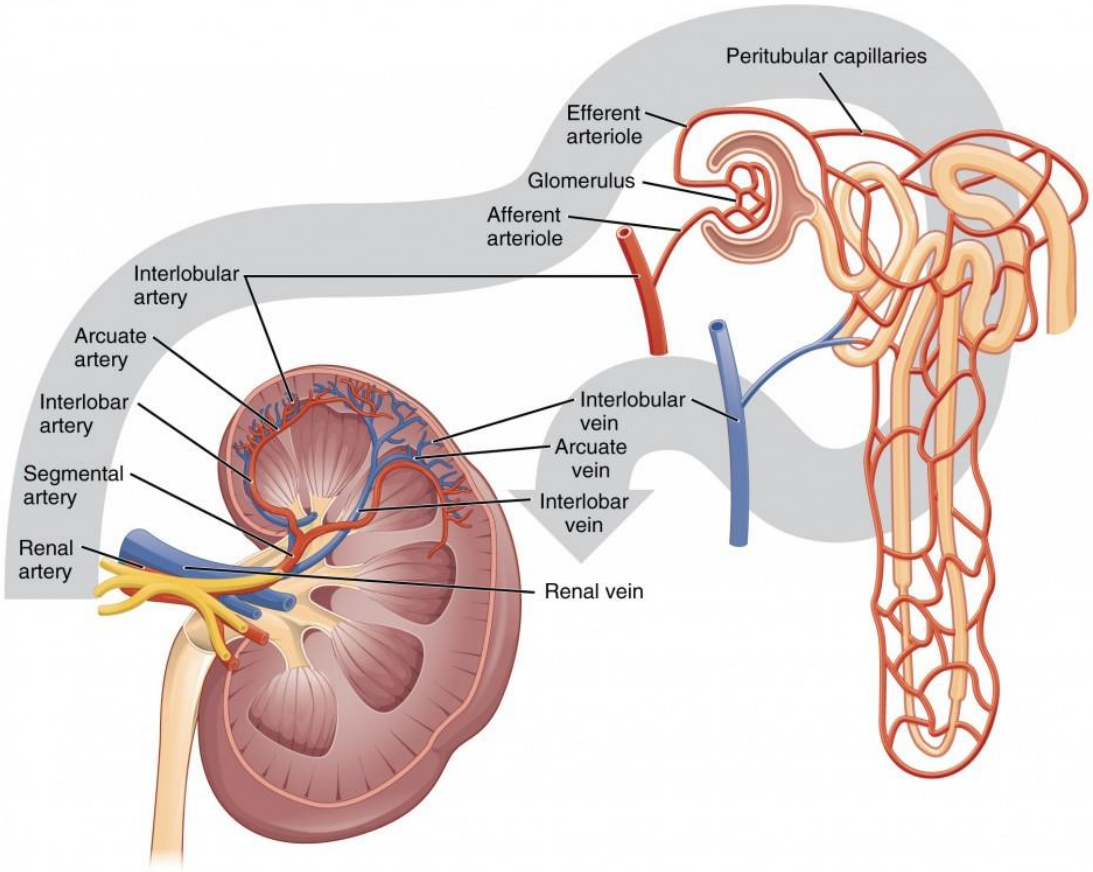
1- Proximal convoluted tubule: which is extend from corpuscle to following part of tubule
2- Loop of Henle: located between proximal convoluted tubule and following part of tubule (distal convoluted tubule)and consist of
   a- descending limb
   b- hairpin loop
   c- ascending limb
3- Distal convoluted tubule: it is last part of renal tubule extend from loop of henle to collecting duct.



Nephron blood supply:

Kidney receive blood by **renal artery**, which is divided inside the kidney into smaller branches called **interlobar branch**, each interlobar branch divided into **arcuate branches** and each arcuate branch divided into **interlobular branches.**

Each interlobular branch move toward outer side of kidney and many arterioles project from it, each arteriole enter one glomerulus, this arteriole called **afferent arteriole.** After exit of arteriole from corpuscle called efferent arteriole and change to capillary surround the tubules of same nephron called **peritubular** capillary



Plasma Volume

The kidneys receive about 1.1 L/min, or about 20% of the cardiac output. A normal hematocrit (Packed Cell Volume) is 0.45, ie, 45% of the blood volume is composed of red blood cells and the remaining 55% is plasma. Typical renal blood flow (RBF) is 1.1 L/min. The **renal plasma flow (RPF)** 0.55×1.1 L/min = 605 mL/min. The typical glomerular filtration rate (GFR)**(GFR: It is the volume of fluid filtered from glomerular arterioles to Bowman's capsule per unit of time)** is about 125 mL/min. Thus, of the 605 mL of plasma that enters the **glomeruli** via the **afferent arterioles**,

125 mL, or 20%, filters into Bowman's space. The remaining 480 mL passes via the **efferent arterioles** into the **peritubular capillaries**. This ratio—GFR/RPF—is known as the ***filtration fraction***.

Renal Processes:

The working structure of kidney are nephrons and collecting tubules. Urine formation need for three main processes occur in the nephrons and tubules, these are :

1- **Filtration** is the process by which water and solutes in the blood leave the vascular system through the filtration barrier and enter Bowman's space (a space that is topologically outside the body).
2- **Reabsorption** is the process of moving substances from the lumen across the epithelial layer into the surrounding interstitium and then move to surrounding blood vessels.
3- **Secretion** is the process of moving substances into the tubular lumen from the cytosol of epithelial cells that form the walls of the nephron.

Glomerular Filtration (The First Step in Urine Formation) and Composition of the Glomerular Filtrate

The rate of filtration from glomerular capillary to Bowman's capsule depend on four forces or pressures they are:

1- Capillary hydroststic pressue
2- Capillary oncotic pressure
3- Bowman's hydrostatic pressure
4- Bowman's oncotic pressure

Hydrostatic pressure depend on solutes amount in solution except protein.

Oncotic pressure depend on protein amount in solution.

Capillary hydrostatic pressure push fluid to transport from capillary to Bowman's capsule, but Capillary oncotic pressure attract the fluid to stay in the capillary.

Bowman's hydrostatic pressure push the fluid to transport from capsule to glomerular capillary, but Bowman's oncotic pressure attract the fluid to stay in capsule.

The value of Bowman's oncotic pressure is zero. Why?

$NFP = (P_{GC} - \pi_{GC}) + (P_{BC} - \pi_{BC})$

where P_{GC} is glomerular capillary hydraulic pressure, π_{BC} is oncotic pressure of

fluid in Bowman's capsule, P_{BC} is hydraulic pressure in Bowman's capsule, and

π_{GC} is oncotic pressure in glomerular capillary plasma.

Because there is normally little protein in Bowman's capsule, π_{BC} may be taken as **zero** and not considered in our analysis. Accordingly, the overall equation for GFR becomes

GFR = $Kf\,(P_{GC} - P_{BC} - \pi_{GC})$.

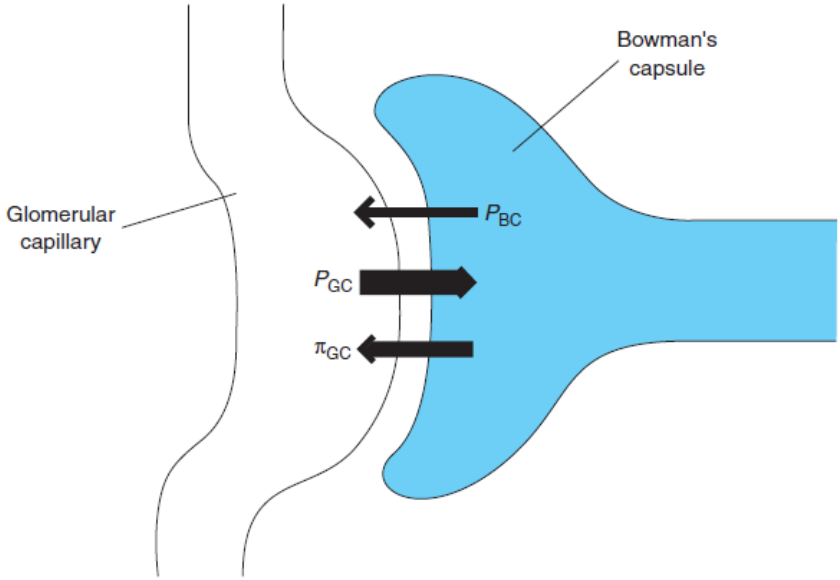


Table 2–1. Estimated forces involved in glomerular filtration in humans

Forces	Afferent end of glomerular capillary (mm Hg)	Efferent end of glomerular capillary (mm Hg)
1 Favoring filtration	60	58
Glomerular-capillary hydraulic pressure, P_{GC}		
2 Opposing filtration	15	15
a Hydraulic pressure in Bowman's capsule, P_{BC}		
b Oncotic pressure in glomerular capillary, π_{GC}	21	33
3 Net filtration pressure (1 – 2)	24	10

So, the value of capillary hydrostatic pressure should be more than Bowman's hydrostatic pressure and capillary oncotic pressure to be able to push of fluid and waste products of blood to Bowman's capsule.

For practical assessment to kidney function there is another law to calculate GFR

$$GFR = \frac{\text{urine creatinine concentration} \times \text{u}rine\ volume}{\text{plasma creatinine concentration}}$$

-The volume of urine during 24 hours.

Water Excretion:

When over-hydration (drink large volume of water) occur, the renal system produce or excrete large volume of dilute urine (clear color urine) but during dehydration, the kidney excrete small volume of concentrated urine (dark yellow color urine).

The main reabsorption site of water is cortical collecting duct. During over-hydration the most water pass through collecting duct without reabsorption and large volume of diluted urine excreted, this condition called **water diuresis** when occur as result drink of large volume of water and water called **physiological diuretic**.

During dehydration (loss of water) state, most water reabsorbed in collecting duct and return to interstatial fluid to maintain fluid balance in body. The collecting duct cells reabsorbed water under effect of **Anti-diuretic hormone (ADH) (Vasopressin)** which is secreted from posterior lobe of pituitary gland, and **Aldosterone** which is secreted from cortex of adrenal gland.

Diuretics:

It is any substance causing increase in excretion of urine. In medicine, diuretics are used to treat heart failure, liver cirrhosis, hypertension, poisoning, and certain kidney diseases.

Diuretics types:

1- **loop diuretic**

Loop diuretics, such as **furosemide**, inhibit the body's ability to reabsorb sodium at the ascending loop in the nephron, which leads to an excretion of water in the urine, whereas water normally follows sodium back into the extracellular fluid. Other examples of high ceiling loop diuretics include **ethacrynic acid** and **torasemide**.

2- **Thiazides**

Thiazide-type diuretics such as **hydrochlorothiazide** act on the distal convoluted tubule and inhibit the sodium-chloride symporter leading to a retention of water in the urine, as water normally follows penetrating solutes.

3- Carbonic anhydrase inhibitors

Carbonic anhydrase inhibitors inhibit the enzyme carbonic anhydrase which is found in the proximal convoluted tubule. This results in several effects including bicarbonate accumulation in the urine and decreased sodium absorption. Drugs in this class include **acetazolamide** and **methazolamide**.

4- Potassium-sparing diuretics

These are diuretics which do not promote the secretion of potassium into the urine; thus, potassium is retained and not lost with other diuretics. Like **spironolactone**, **amiloride** and **triamterene**.

5- Calcium-sparing diuretics

The term "calcium-sparing diuretic" is sometimes used to identify agents that result in a relatively low rate of excretion of calcium.

6- Osmotic diuretics

Osmotic diuretics (e.g. **mannitol**) are substances that increase osmolarity but have limited tubular epithelial cell permeability.

Regulation of Potassium Secretion

The most important factors that *stimulate* potassium secretion by the principal cells include

(1) increased extracellular fluid potassium concentration

(2) increased aldosterone

(3) increased tubular flow rate.

One factor that **decreases** potassium secretion is increased hydrogen ion concentration (**acidosis**).

Micturition

Micturition is the process by which the urinary bladder empties when it becomes filled. This involves two main steps: **First**, the bladder fills until the tension in its walls rises above a threshold level. the **second** step, which is a nervous reflex called the ***micturition reflex*** that empties the bladder. the micturition reflex is an autonomic spinal cord reflex.

Urinary Bladder

The urinary bladder is a smooth muscle chamber composed of two main parts: (1) the **body**, which is the major part of the bladder in which urine collects, and (2) the **neck**, which is a funnel-shaped extension of the body, passing into the urogenital triangle

and connecting with the urethra. The lower part of the bladder neck is also called the **posterior urethra** because of its relation to the urethra.

The smooth muscle of the bladder is called the **detrusor muscle**. Its muscle fibers extend in all directions and, when contracted, can increase the pressure in the bladder. Thus, *contraction of the detrusor muscle is a major step in emptying the bladder*. On the posterior wall of the bladder, lying above the bladder neck, is a small triangular area called the **trigone**. At the lowermost apex of the trigone, the bladder neck opens into the posterior urethra.