Sheet No.

# Physiology

## Genitourinary system

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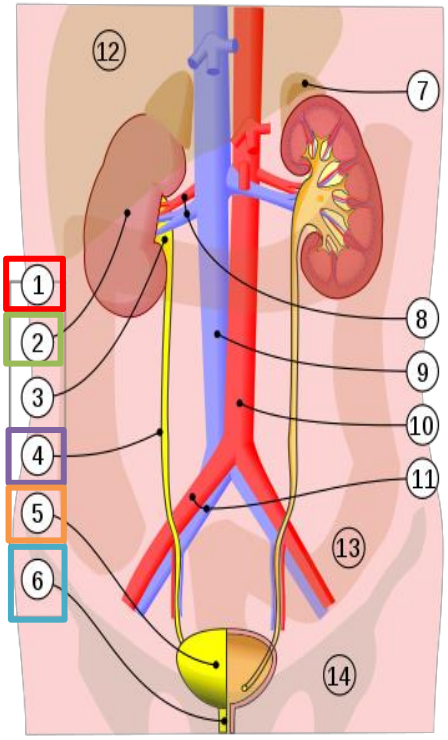
**Learning Objectives:**

- 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 the nephron's blood supply.
- Understand the relation between the structure and function of the nephron unit.

## The Urinary System

Organs of the urinary system (1): **the kidneys, renal pelvis, ureters, bladder, and urethra**

The urinary system is composed of **2 kidneys (2)** (one on the right and another on the left with blood supply composed of a renal artery and renal vein for each one) which perform most of the work of that system (other parts serve as passageways or storage organs), with an attachment of **2 ureters (4)** that transport the urine from the kidneys to the **urinary bladder (5)** which stores it (as the urine formation is a continuous process) until it is convenient for the person to urinate -urination process in physiology is known as **micturition**-, the last part which is the **urethra (6)** discharges urine from the body.




## Urinary System Function

### 1- Filters Waste Products from Blood

- Excretion of water and sodium chloride (NaCl) is regulated in conjunction with the 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 (Bilirubin), 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 (urine formation = excretion).

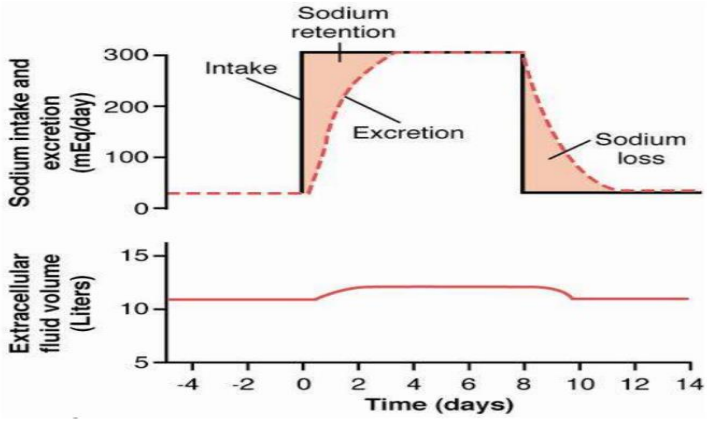
## 2- Conserves Valuable Nutrients

The urinary system ensures (by reabsorption) that glucose, amino acids, and other valuable nutrients are not lost from the urine. Kidneys can also use glutamine to release glucose in gluconeogenesis. – we will not have any of these substances in the urine –

## 3- 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 -by reducing or increasing the amount excreted outside the body in the urine-

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




## 4- Regulates Blood pH

Secretion ↑

- The urinary system regulates blood pH by regulating the number of **H+** and **bicarbonate ions** (HCO3-) lost in the urine.
- The kidneys work in concert with the lungs to regulate the pH within narrow limits of buffers within body fluids.

## 5- Regulates Blood Volume (the kidney is the main regulator of fluid homeostasis)

The urinary system regulates blood volume by: **(and pressure)**

1) releasing **renin**, a hormone that after a series of reactions eventually restricts salt and water loss at the kidneys (Renin-Angiotensin-Aldosterone system). After many steps renin will result in the production of a peptide called **angiotensin-2** which has different functions, one of them is to retain salt -and as a result water in the body-

2) adjusting the volume of water lost in the urine

## 6- Regulates RBC Production

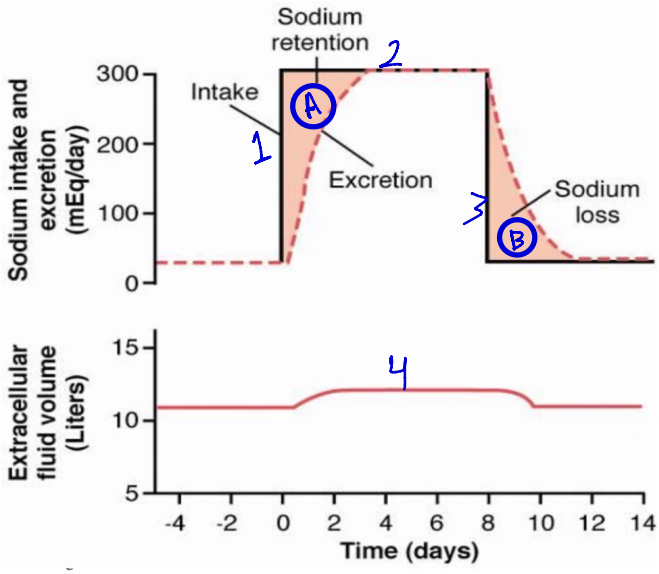
If oxygen levels in the blood are low, the kidneys release **erythropoietin**, a hormone that stimulates the hemocytoblasts (stem cells in the bone marrow) to increase red blood cell formation. Having more RBCs allows the blood to transport more oxygen.

## 7- Stores and excretes urine

The **bladder** stores the urine until it is convenient to excrete it, and the **urethra** transports urine from the urinary bladder to the outside of the body

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

This graph show the importance of the kidney to regulate homeostasis of electrolytes and fluids in our body especially in extracellular fluid compartments.




1) So, If intake of salt has increase 10 fold,then the execration rate of salt by kidney will increase gradually ( Not Fast) until execration rate equals intake rate of soduim chloride (2) , but doesn't happen fast (it takes 2-3 days) until it happened.

(A) Part of sodium will remain in the body regardless of the equal rates of intake and execration, this is because it takes time until the rate of execration is adjusted to an extent equal to the intake.

As long as the intake does not change, this amount will remain in the body (3) until the person returns to the normal intake of sodium after that , The kidney will take time to get rid of this salt, because the change requires hormonal changes, so it takes time.

(4) Increase in extracellular fluid because the osmolarity (sodium intake).

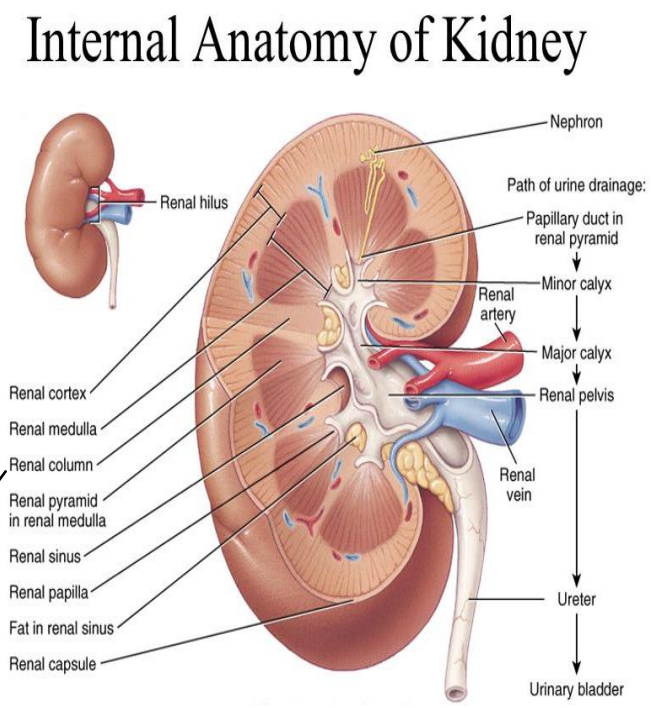
## 8- Produces and secretes hormones: (Endocrine Gland)

- **Calcitriol**: The active form of **vitamin D,** important for calcium absorption in the digestive system (the activation of Vitamin D takes place in the kidney).
- **Renin**: activates the renin-angiotensin-aldosterone system, thus regulating blood pressure regulation & Na+, K+ balance by adjusting sodium reabsorption.
- **Prostaglandins/kinins**: bradykinin = vasoactive, leading to modulation of renal blood flow & along with angiotensin II affect the systemic blood flow (it's contraindicated to take any medications that blook the synthesis of prostaglandins in people who are suffering from reduced kidney functions i.e. NSAIDs such as diclogesic, and the painkillers such as profen)
- **Erythropoietin**: stimulates red blood cell formation in bone marrow

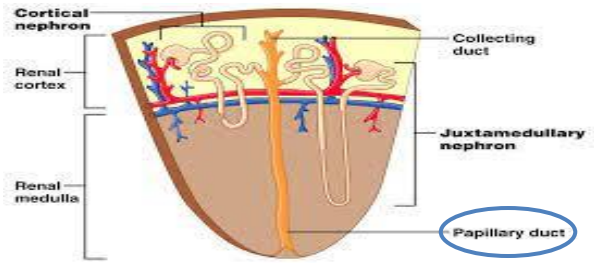
## Kidney Structure

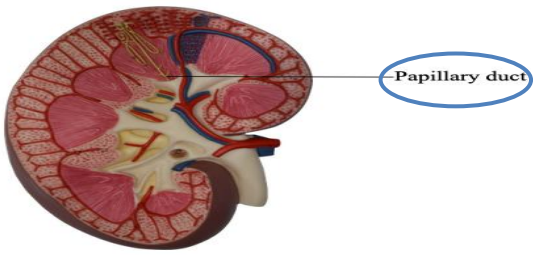
**"Nephron is the functional unit of kidney"**

- Is composed of an outer layer, dense and lighter in color known as the **Renal cortex** and an inner layer known as the **Renal medulla,** where we have pyramidal shapes **(Renal pyramids)** each one of them has a tip known as **Renal papilla** which is the end of the **papillary duct** that has formed urine and empties at the renal papilla into structures known as **Major calyces** and **Minor calyces**, then we will have a larger container of urine known as **Renal pelvis** which will empty all formed urine into the **ureter.**

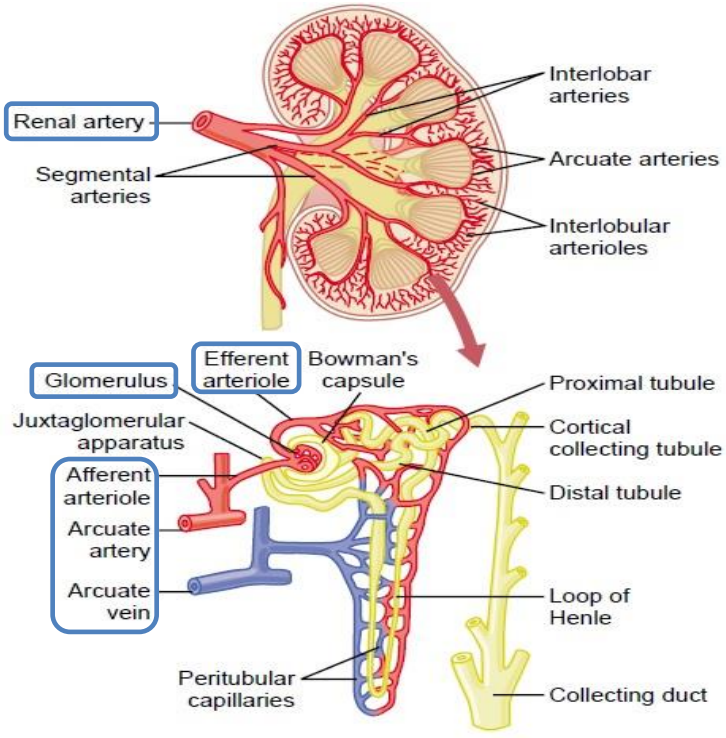



- **The hilum** of the kidney is composed of the **Renal artery and Renal vein** (blood comes in through the renal artery to supply the structures of the kidney and then will return back via venules and veins to be collected in the Renal vein into the systemic venous circulation)
- **Renal columns** separate renal pyramids
- **Renal capsule** is the covering connective tissue



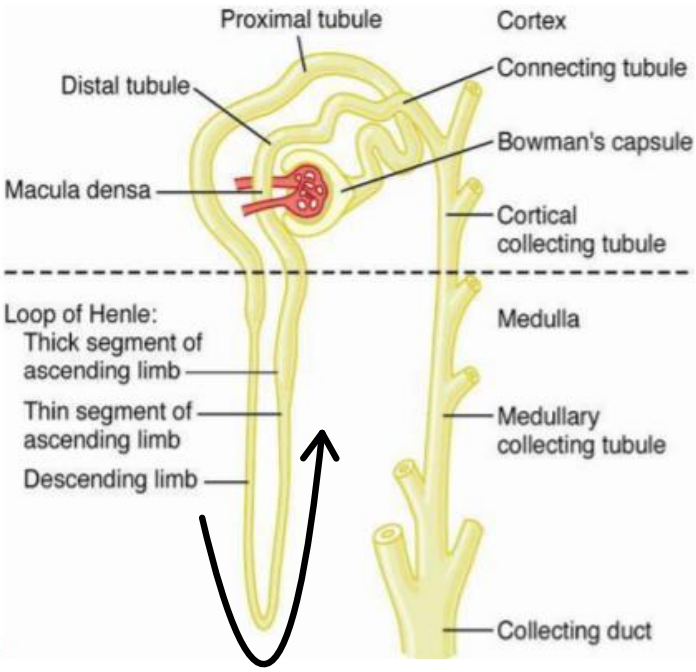



## Major blood vessels of the kidney




- There is a **renal artery** and **renal vein** for each kidney
- we can notice that the renal artery branches and gets smaller and smaller to distribute blood all over the parts of the kidney
- in the venous system, we have small venules and small veins that anastomose to make larger veins and end up in the renal vein
- A small branch of a renal artery called an **arcuate artery** will give rise to an **afferent arteriole** which will end in the nephron and give rise to a capillary system called the **renal glomerulus.** The glomerulus gives rise to an **efferent arteriole** (this is an exception of the capillary beds as we have afferent arteriole and efferent arteriole with no venule). The efferent arteriole will branch again and give rise to many capillaries known as **Peritubular capillaries** that surround the tubular system of the nephron
- Filtration process takes place in the glomerulus

## Structure of the nephron




- there is a balloon-like structure which is called the **Renal capsule** or the **Bowman's capsule**, the **glomerulus** is touching the outer surface of the bowman's capsule and somehow bushing inward, we can say that the bowman's capsule is surrounding the glomerulus
- Together the bowman's capsule and the glomerulus are called the **renal corpuscle**
- The capsule is attached to a tubular system that starts very convoluted متعرج (**the proximal convoluted tubule PCT**), the next part of the tubular system looks

like a hairpin loop which is **the loop of Henle (LH)** composed of a **thin descending segment (limb), thin ascending segment (limb), and thick ascending segment (limb).** The tubule gets again convoluted forming **the distal convoluted tubule (DCT)** which is connected to the **connecting tubule** and then to **the collecting tubule and the collecting duct (CD)** which will collect so many connecting tubules together in one tubule. The collecting tubule will end up at the tip of **the renal papilla**

- Each kidney is made up of 1 million of nephrons.
- Depending on the location of the nephron we have two types of nephros, **cortical nephrons** (which lie in the cortex) -represent the majority of nephrons- and **Juxtamedullary nephrons** which are on the borderline between the cortex and the medulla and those extend very deep in the medulla
- There is adifferent capillary structure for each type, in the juxtamedullary nephron, the peritubular capillaries are called the **vasa recta,** they have a unique distribution between the venous and arterial capillaries as they lie parallel to each other
- **Juxamedullay nephrons** are very important in concentrating urine **(LONGER)**
- **The cortical nephron** is short, most of it lies in the cortex

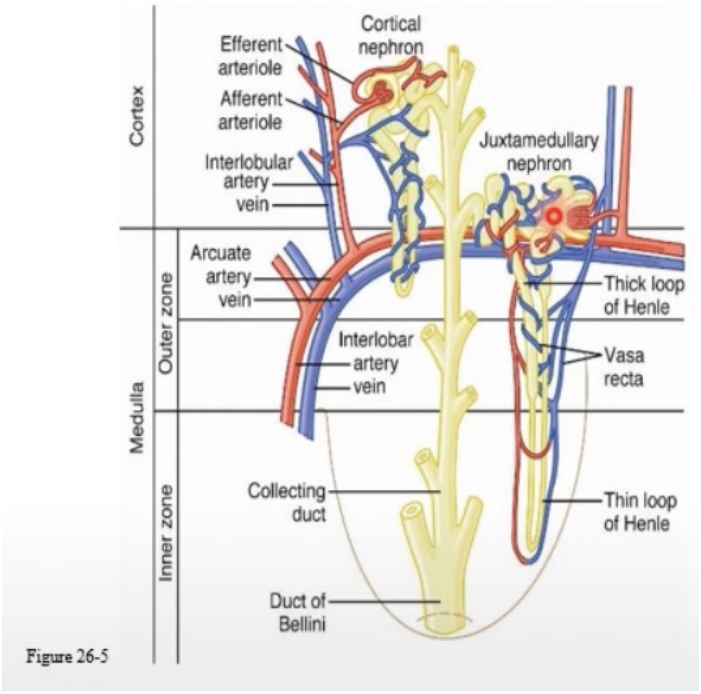
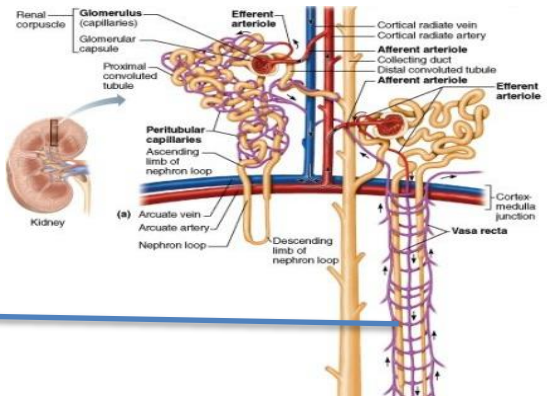


Figure 26-5

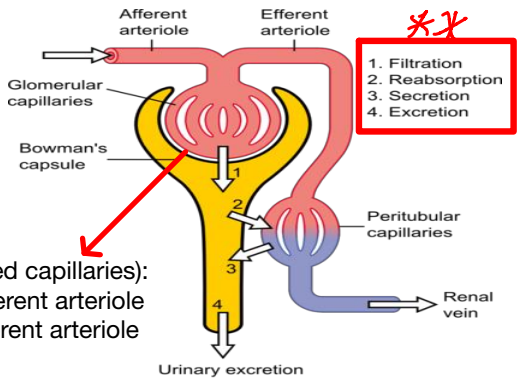
| The two types of nephrons and their features | | |
|---|---|---|
| **Feature** | Juxtamedullary nephron | Cortical nephron |
| **Percentage** | 15% | 85% |
| **Renal capsule situation** | Inner cortex is near medulla | Outer cortex is near periphery |
| **Tubule blood supply** | Vasa recta | Peritubular capillaries |
| **Function** | Concentrates urine (mainly), and also forms urine | Forms urine |
| **Loop of Henle** | Long | short |
| | Hairpin bend penetrates up to the tip of papilla | Hairpin bend penetrates only to outer zone of medulla |

The ascending limb of the juxtamedullary nephron contains thick and thin portions while we can't differentiate between the different parts of the loop

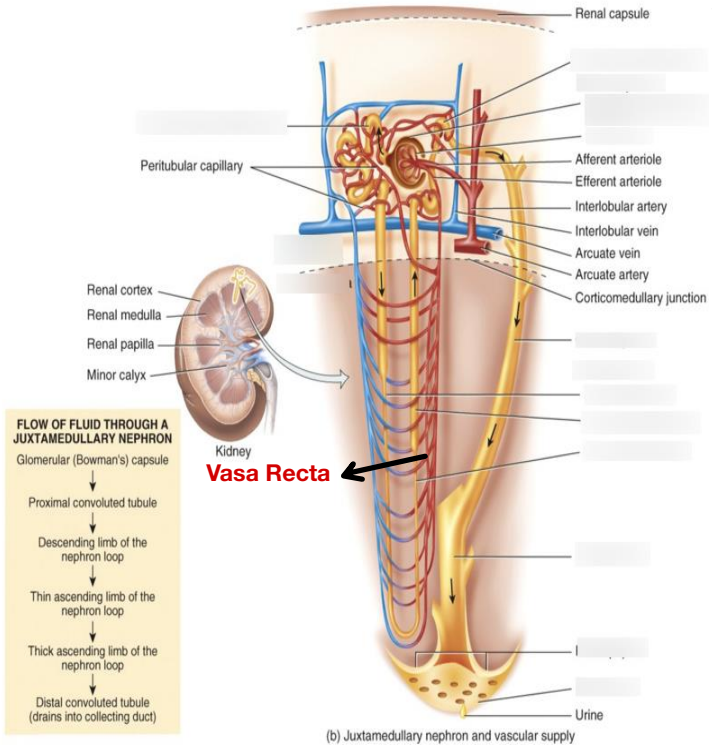
Here we can notice the unique distribution of the capillaries in the vasa recta

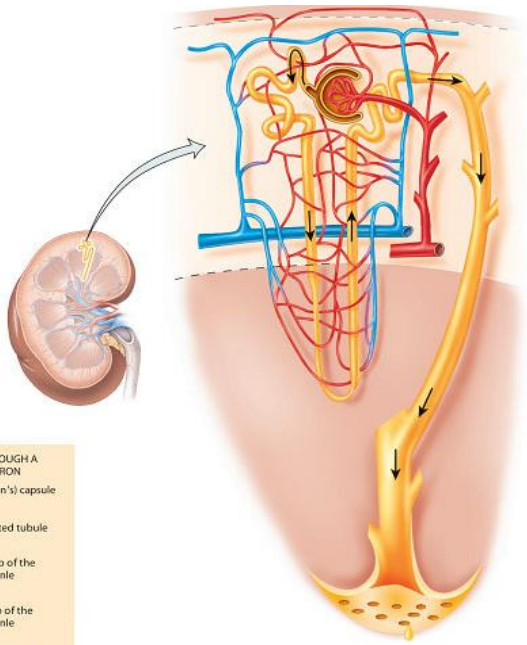


Blood travels from the **afferent arteriole** to a ball of capillaries in the nephron called a **glomerulus** and then leaves the nephron via the efferent arteriole. Blood travels from efferent arteriole to the peritubular capillaries and vasa recta




Glomerular(Bed capillaries):
Start with Afferent arteriole
End with Efferent arteriole



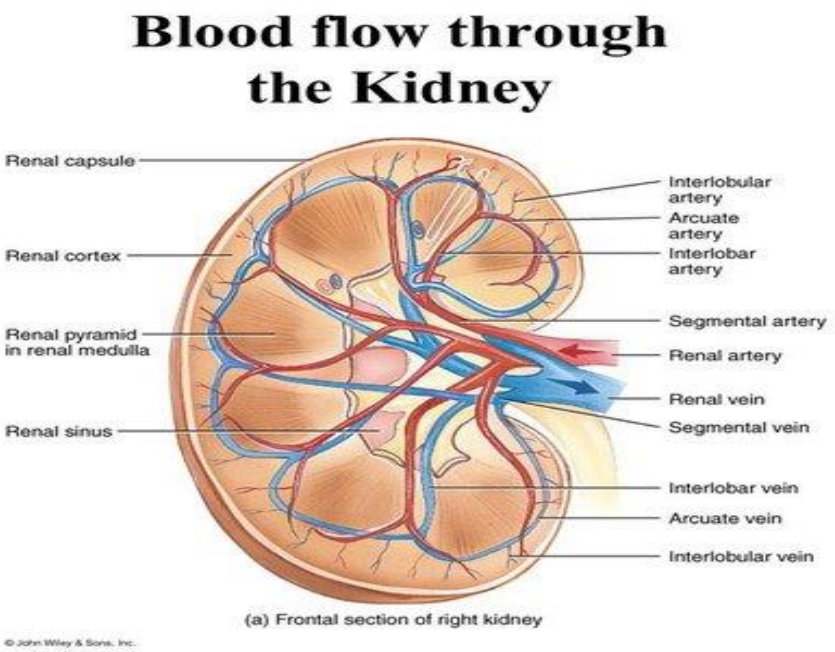



FLOW OF FLUID THROUGH A CORTICAL NEPHRON
Glomerular (Bowman's) capsule
Proximal convoluted tubule
Descending limb of the loop of Henle
Ascending limb of the loop of Henle
Distal convoluted tubule (drains into collecting duct)

Blood supply of the juxtamedullary nephron

Notice the unique distribution of the peritubular capillaries (vasa recta) where arterial and venous capillaries are parallel to each other, important for the function of that type of nephron which is to concentrate the urine

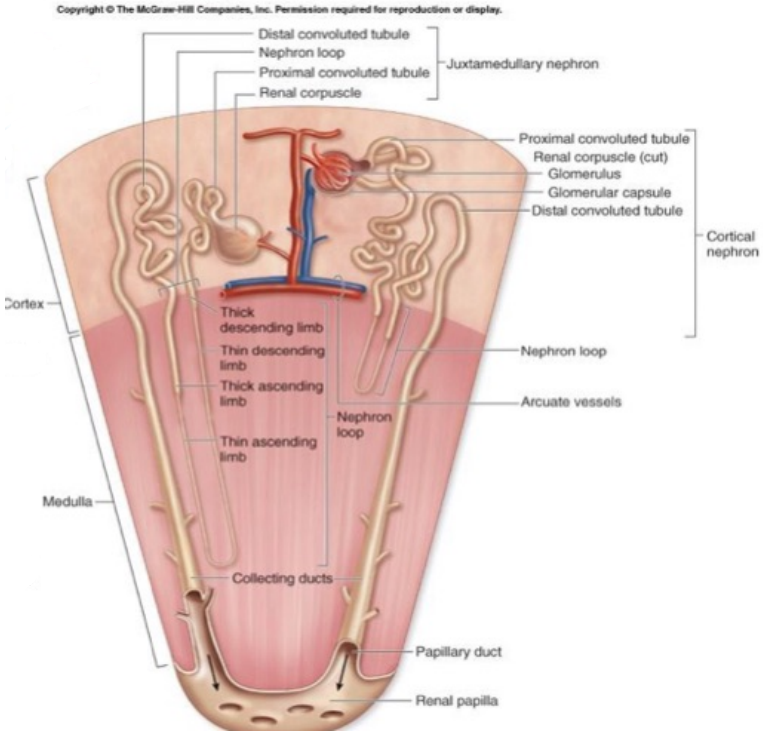
Blood supply of the cortical nephron

# The Functional Unit of The Kidney?

**ANS: Is the nephron.**

- **Each kidney is made up of 1 million of nephrons.**
- Each nephron is made up of the following:




**1-Renal Corpuscle:**

I-Bowman's Capsule

II-Glomerulus

**2-Renal Tubules:**

-Proximal Convoluted Tubule (PCT) -

-Loop of Henle(LH)

-Distal Convoluted Tubule (DCT) -

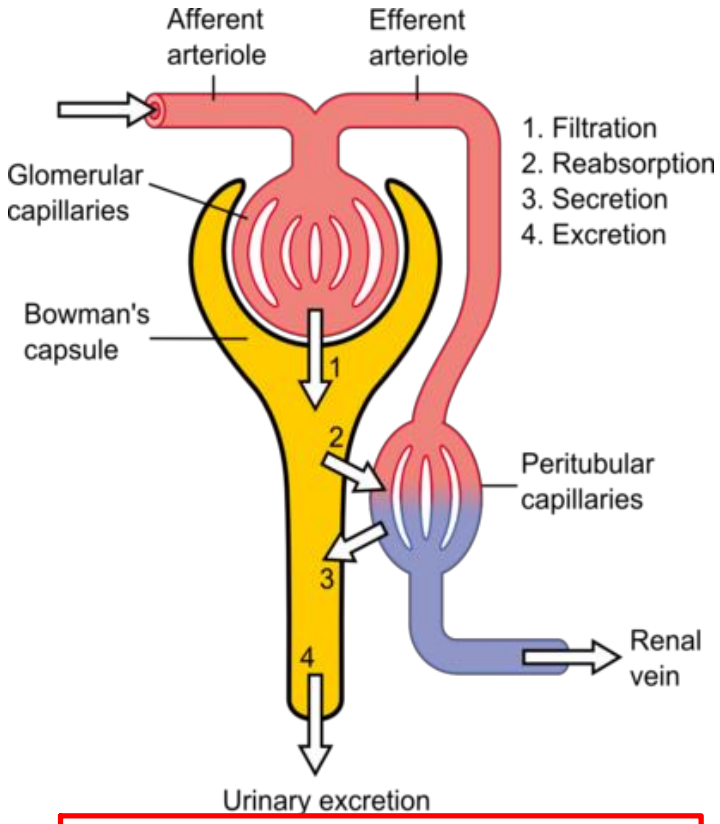
-Collecting Duct (CD)

**VERY IMPORTANT NOTE!! :**

The change in the number of nephrons is always decreasing with an increase in age (especially after the age of forty), and this means that the change in the number is irreversible.That's mean,New nephrons cannot be formed and the damaged ones cannot be repaired, as it was found that the percentage of the decrease is 10% within 10 years after the age of forty, which means that by the age of 80, the person will have lost 40% of his nephrons, **but its effect is not great because the remaining nephrons perform the function of the damaged nephrons.**

# Basic mechanisms of urine formation

Blood comes through the **afferent arteriole** and passes through the capillary system (**glomerular capillaries**) where it gets filtered (**filtration**, the first process of urine formation), then the blood will come out of the glomerulus via the **efferent arterioles** and then will give rise to peritubular capillaries that will surround the tubular system with arterial and venous sides where the second process of urine formation (**reabsorption**) where some of the constituents of the filtered fluid will be reabsorbed back to the circulation because they are important to the body. The third process (**secretion**) occurs in the opposite direction, from the peritubular capillaries some of the waste products get eliminated directly into the filtered fluid adding up to the urine. Finally, urinary **excretion happens**

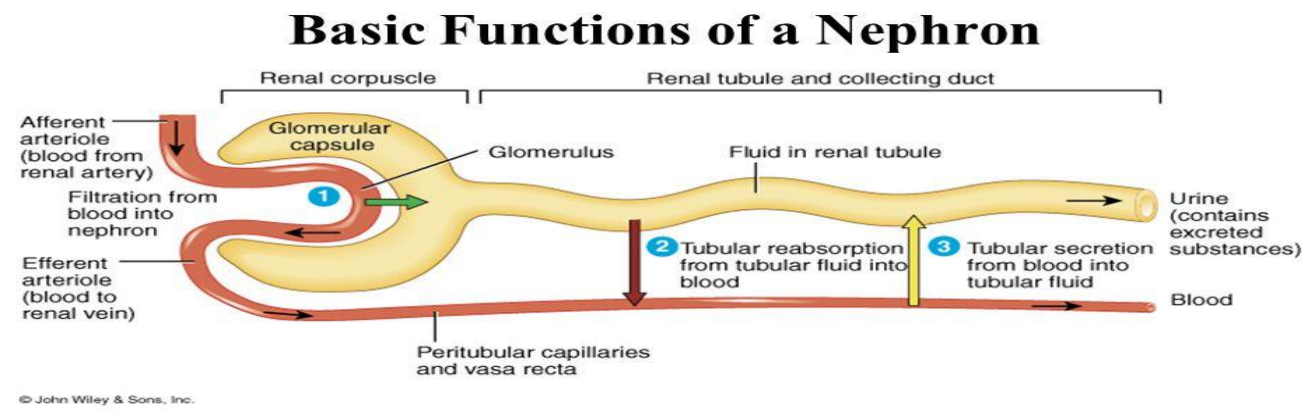



Excretion = Filtration – Reabsorption + Secretion

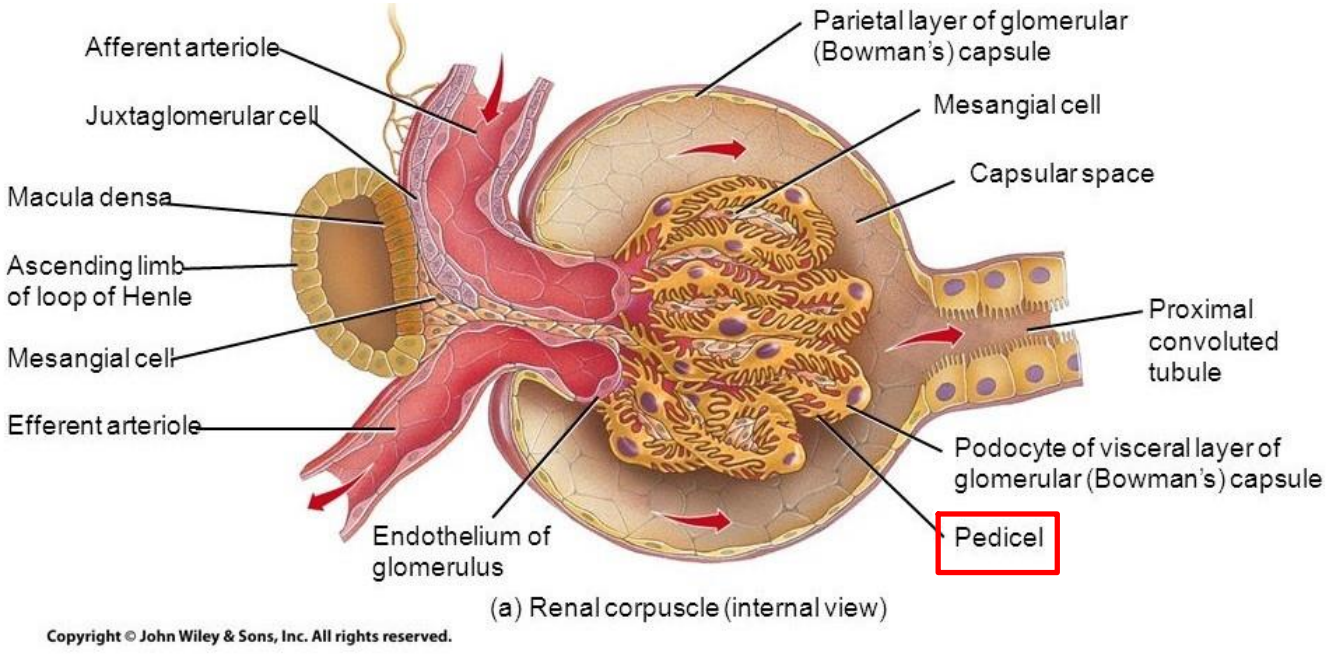
• **Filtration**: Passive (depends on the hemodynamic forces, in the glomerulus that ends up with filtering fluid there will be built up of pressure that will draw fluid outside the glomerulus), somewhat variable, not selective (except for proteins), averages 20% of renal plasma flow (20% of the plasma flow through the glomerulus will be filtered and 80% will remain unfiltered)**……..(Without Energy)**

• **Reabsorption**: highly variable and selective (because it is mostly an active process and a large extent of that process takes place through selective transporters) most electrolytes (e.g. Na+, K+, Cl-) and nutritional substances (e.g. glucose) are almost completely reabsorbed -all of these can't be diffused by simple diffuse-; most waste products (e.g. urea) are poorly reabsorbed

• **Secretion**: highly variable (because it depends on the availability of the substances that should be secreted); important for rapidly excreting some waste products (e.g. H+), foreign substances (including drugs), and toxins**…….“HIGHLY SELECTIVE “**

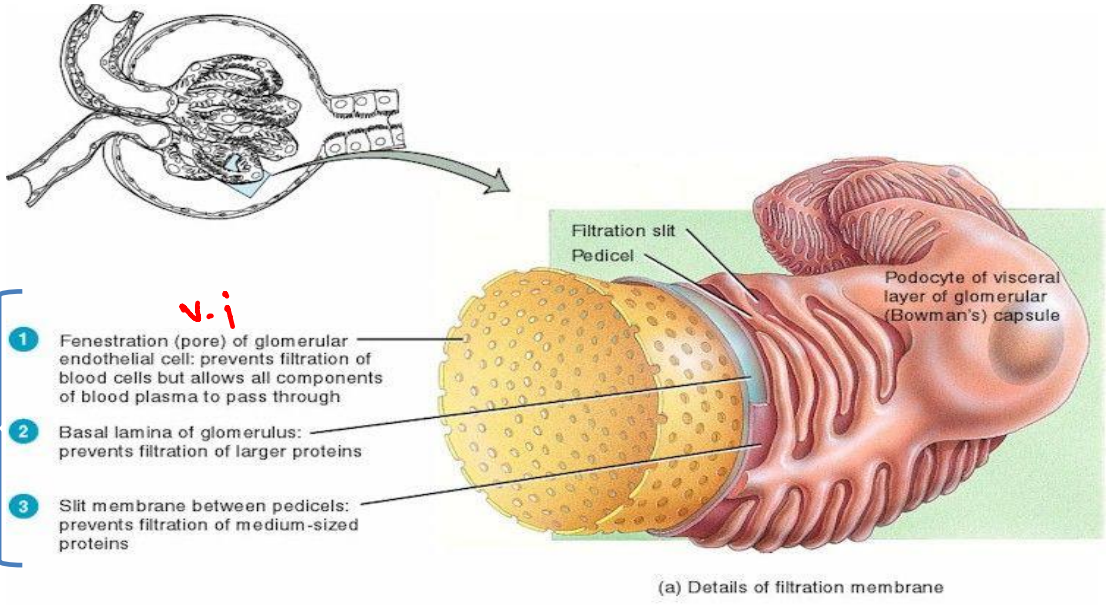



Histology of renal corpuscle



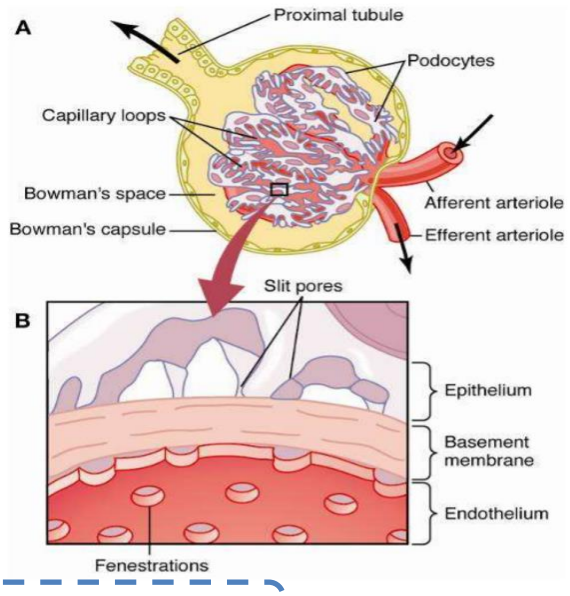

- **Glomerular or Bowman's capsule:**
  - Outer: simple Squamous epithelium
  - Inner (Visceral): Podocytes that wrap around the glomerular capillaries
- **Capsular space:** the space between the outer and inner layers of the capsule which is filled with the filtered fluids
- **Juxtaglomerular cells:** modified smooth muscle cells of the wall of afferent (or efferent) arterioles that are proximate to the Macula Densa
- **Macula Densa:** cells in the final part of the thick ascending part of the loop of Henle or sometimes the distal convoluted tubule (involved in renal autoregulation, will be discussed later)
- **Mesangial cells:** are contractile cells that lie in the clefts between afferent and efferent arterioles, their function is to regulate the surface area of filtration
- Juxtaglomerular cells are part of a structure called **Juxtaglomerular Apparatus** formed by the macula densa cells, it's also important in the autoregulation of the renal function

## Filtration membranes




Glomerular capillaries

- The basal lamina contains negatively charged fibers, which will prevent negatively charged proteins from passing through (Albumin can theoretically pass through the pores of the endothelial cells but there will be repulsion when it reaches the basal lamina
- Glomerular or Bowman's Capsule: Inner (Visceral): Podocytes that have projections called pedicles wrap around the glomerular capillaries, the slit membrane between pedicles prevents filtration of medium-sized proteins




## 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:
  - **Principal Cells**: contains receptors for ADH and Aldosterone.
  - **Intercalated Cells**: Blood PH regulation

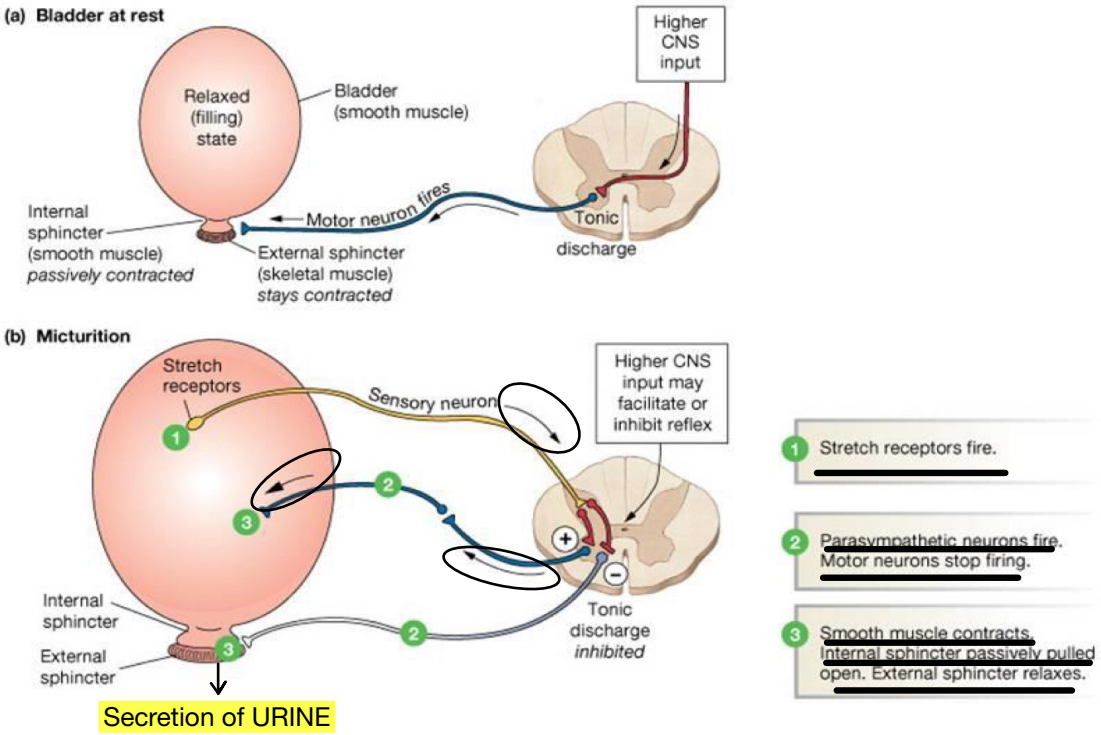
الله يعطيكم العافية و يبارك أوقاتكم

# Micturition

**From the kidneys urine flows down the ureters to the bladder propelled by peristaltic contraction of smooth muscle. The bladder is a balloon-like bag of smooth muscle = detrussor muscle, contraction of it empties bladder during micturition.**

**• Voluntary and involuntary muscle contractions.**
**• Bladder can hold 700-800 ml ( differes between males and females)**
**• Volumes exceeding (200-400)stretch bladder walls and initiate micturation reflex:**
**• Spinal reflex (micturaition center in the spinal cord):**

**1-Parasympathetic impulses from the spinal cord causes bladder to contract and the Internal urethral sphincter to relax.**
**2-Internal sphincter (smooth muscle) opens.**
**3-Simultaneously mict. C inhibits the external sphincter (skeletal muscle) and then it relaxes. ( This part can be controlled voluntary)**




Secretion of URINE