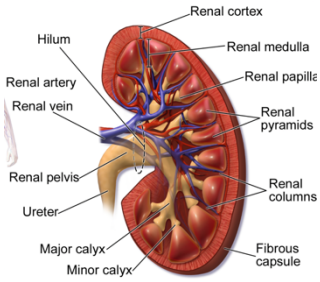
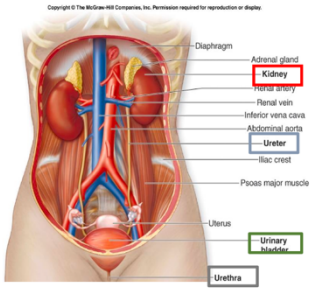
Sereen Draghmeh

The Urinary System

- Urinary system is composed of two kidneys (one on the left and one on the right) and it participates in most of the functions of the urinary system
- Structures in the kidney
  - Hilum
    - Composed of
      - Blood supply
        - Renal artery
          - It enters the kidney to supply the renal structures
          - Comes from abdominal aorta
        - Renal vein
          - Leaves the kidneys to drain into the inferior vena cava
      - Nerve supply
      - lymphatics



  - Ureter
    - Collects the formed urine
    - Is a passage way from the kidneys to the urinary bladder (sac like structure) so that urine is stored there
    - When the time is right and it is convenient for the person to perform the urination process, the urethra will discharge the urine outside the body
- 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

1. <u>Filters Waste Products from Blood</u>

a. during the body's metabolic activities there are going to be byproducts produced along the way, so we will have to eliminate them or else they will accumulate and become toxic to our system

b. They should be eliminated once they are produced and shouldn't stay in our body for a long time

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

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

i. 1. **ammonia** and **urea** (both formed when amino acids are broken down),
ii. 2. **uric acid** (formed when nucleic acids are broken down),
iii. 3. **creatinine** (from muscles).
    1. From creatine phosphates
iv. 4. **end products of hemoglobin metabolism, hormone metabolites foreign substances**
    1. (e.g., drugs, pesticides, & other chemicals ingested in the food)
    2. Hemoglobin is going to be broken down and the dye that is called bilirubin should be eliminated
    3. And the hormones that are going to be broken down and the byproducts of it should be elimianted

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

The kidney forms urine via three processes:

1. Filtration- kidney acts as a strainer so blood will pass through, some of the components will pass to the other side while others wont be able to pass through to the other side
2. Reabsorption process- brings back the good substances that we need for our body and brings it back to our system
3. Secretion- which will be discussed later

The wastes leave the body as urine.

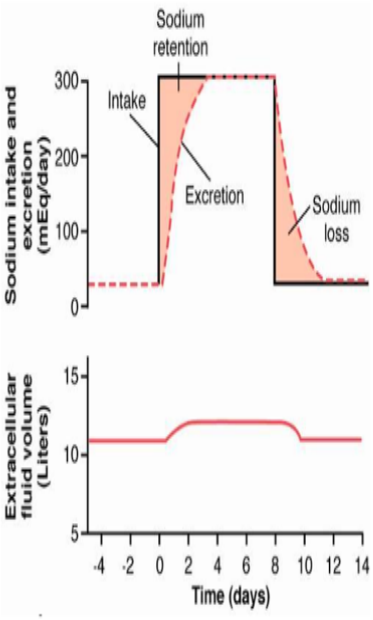
2.Conserves Valuable Nutrients

a. During the filtration process while the kidneys are filtering and removing the bad waste products, some valuable nutrient and fluids will also be filtered and removed but we need these valuable nutrients since our body spent so much time and energy in the first place to have ,so the kidneys will perform another process called reabsorption to bring back these substances
b. The kidney can form glucose from other resources when the body is in short of glucose in a process called gluconeogenesis (production of glucose from amino acids)
c. 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.

3.Regulates Ion Levels in the Plasma

a. It has this capability because it can adjust the excretion rate of these ions from the extracellular fluid volume
b. So the kidney can adjust the level of excretion and this how it can adjust the ion level in our body
c. 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.
    i. The most important cation in the extracellular fluid is sodium
    ii. In the picture you can see two graphs

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



1. Measures the sodium intake and excretion per day
    a. You can see that the normal intake per day is about 30 mEq per day and at the same time we have normal excretion at which excretion rate equal intake in which this is how it balances the intake with the output
    b. When you increase your intake of salt (by 10x) and reach an intake of 300 mEq, you will see that the excretion rate of the kidney (dashed line) will increase gradually (doesn't work very fast since it requires hormones and transporters – not like the CNS)
    c. It will take 2-3 days for you to excrete the extra sodium intake so that the excretion and intake of sodium is the same
    d. Meanwhile all of that that we are going to have a period where the sodium intake is going to be higher than the excretion so here we will have sodium retention (there is going to be extra sodium retained in our system)
    e. After that the excretion and intake is balanced
    f. By day 8 the person returned to normal
    g. When the sodium intake is lower than normal, the kidneys will gradually adjust the excretion rate, so there is going to be a period where the excretion rate is higher than the intake, so we are going to have here a loss of sodium.
    h. This loss of sodium is equal to the retained sodium in the first place, so they cancel out each other
2. Measures the extracellular fluid volume per day
    a. If you look here we all know that we have more salt in our extracellular fluid
    b. There are going to be changes, and a shift in the fluids from the intracellular to the interstitial to the extracellular resulting in the expansion of the extracellular fluid volume (the extracellular fluid volume will increase due to the increase in retention of sodium)
    c. Once there is excess loss of salt (following it is water) , the extracellular fluid will go back to normal

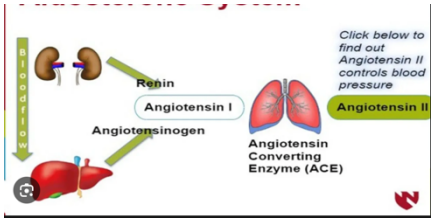
4.Regulates Blood pH

a. The pH is balanced within a very narrow window/range, in which the fluctuation shouldn't be big since it will affect the function of the proteins and cells and the vitality of cells negativity, corrupting the homeostasis of the body

b. So the kidneys needs to regulate the blood pH by adjusting the excretion rate of hydrogen and bicarbonate and it works along with the lungs
c. The urinary system regulates blood pH by regulating the number of H+ and bicarbonate ions (HCO3-) lost in the urine
d. The kidneys work in concert with lungs to regulate the pH in a narrow limits of buffers within body fluids.

5.Regulates Blood Volume

a. As we said , it regulated the blood volume by regulating the electrolytes and ions and fluids
b. When there is an increase in excretion of salt it will be followed by more excretion of fluid since water follows solutes, so if there is more excretion of solutes there will be more excretion of water
c. The urinary system regulates blood volume by:
    i. releasing **renin**, a hormone that after a series of reactions eventually restricts salt and water loss at the kidneys.



        1. Renin enzyme is secreted by certain cells in the kidneys (nephron) in which this enzyme results in the production of angiotensin II that increases blood pressure (in which a decrease in blood pressure stimulates it), and so it will bring back the blood pressure to normal
        2. This is renin aldosterone angiotensin system
    ii. adjusting the volume of water lost in the urine
        1. again as we said water follows solutes so if there is an increase in the excretion of solutes there is going to be an increase in the excretion of water

6.Regulates RBC Production

a. 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.
    i. Kidney also works as an endocrine organ by releasing erythropoietin which regulates RBC formation

7.Produces and secretes hormones:

a. **Calcitriol**: The active form of vitamin D.
    i. Important for bone density and the calcium deposition in bone as well as calcium absorption
b. **Renin**: activates the renin-angiotensin-aldosterone system, thus regulating **blood pressure regulation** & Na+, K+ balance.
    i. Which generates the angiotensin II enzyme which is very important
    ii. Ahs a role in blood pressure regulation and electrolyte balance and excretion of electrolytes and water
c. **Prostaglandins/kinins**: bradykinin = vasoactive, leading to modulation of renal blood flow & along with angiotensin II affect the systemic blood flow

i. Enhancing the blood flow to the kidneys, enhancing the kidney function
ii. That's why we always say that its contraindicated to give a patient of renal disease non steroidal inflammatory drugs (NSAID) because they inhibit the production of prostaglandins so we will lose the vasodilator beneficial effect of the prostaglandins that is need in the patient with renal disease

d. **Erythropoietin**: stimulates red blood cell formation by bone marrow

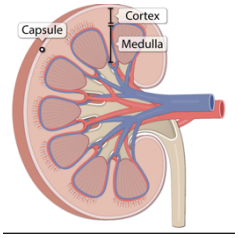
8.Stores Urine

a. The **bladder** stores the urine until it is convenient to excrete it.

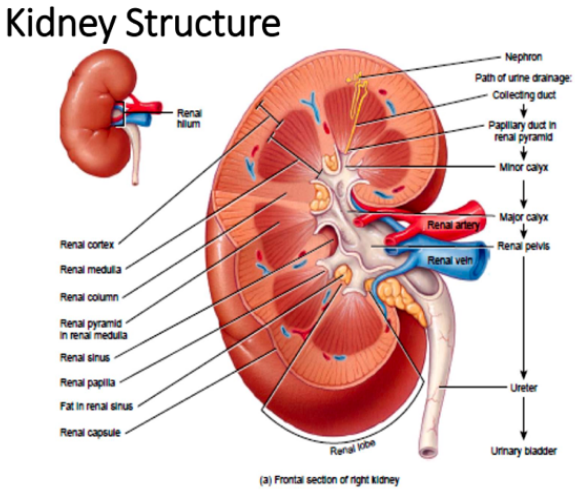
9.Excretes Urine:

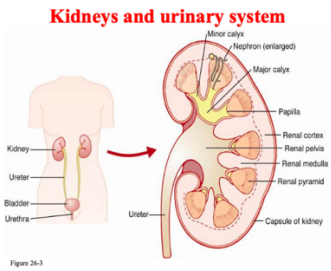
a. The **urethra** transports urine from the urinary bladder to the outside of the body.

The Kidney structure



- From the picture we can see that the kidney is a bean shaped organ
- There are two regions in the kidney:
  - the cortex (outside structure)
  - the medulla (inside structure)
    - The medulla is composed of:
      - Renal pyramids
        - pyramidal structures
        - contain the functional units of the kidneys called nephrons (in the picture only one can be seen) they are very small structures, they are the filters of the kidneys (they produced the filtered fluid)
          - After the filtered fluid is produced it will flow to in tubules to drain into collecting tubules and collecting ducts to reach the tip of the renal pyramids called renal papilla
          - So it will drain into the renal minor calyxes and open up into the major calyxes and then open up to the renal pelvis so urine will drain into these folds and then it will flow to through the ureter to she stored in the urinary bladder
      - Calyx are structured that collect urine
        - We have major and minor calyx
          - Minor calyx collects urine from one medullary pyramid
          - Major calyx collects urine from more than one minor calyx
          - The major calyx then drains it into the pelvis structure



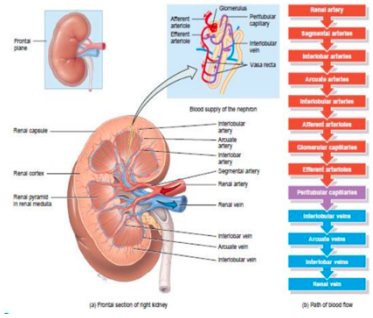


- renal column
  - found in between the renal pyramids
  - composed of connective tissue

Major Blood Vessels of the Kidneys

- the blood supply is very important for the function of the kidneys since it involves the filtration of blood so we need to have high percentage of the cardiac output (about 20%) to be received by the kidneys, this is because the function of the kidneys that requires it not because of the metabolic needs of the kidney
- Blood supply
  - the renal artery enters the kidney and branch into segmental arteries which gives interlobar arteries (notice how its in the columns) and the interlobar arteries will give rise to arcuate arteries and these arcuate arteries will give rise to interLOBULAR arterioles which gives rise to afferent arterioles which gives rise to specialized tuft of capillaries called glomerulus in the nephrons as part of the nephron and then the capillaries (glomeruli) will give rise to efferent arterioles
    - so the afferent arterioles is the one that gives blood supply to the nephron
  - renal artery→segmental arteries→interlobar arteries→arcuate arteries→ interlobular arteries→afferent arterioles→glomeruli (capillaries) →efferent arterioles
- Nephron structure
  - the nephron is composed of a renal corpuscle which is composed of a glomerulus which is a special type of capillary that is highly fenestrated (many pores) so the filtration rate here is high and this tuft comes very close to a cup like/ balloon like structure called bowman's capsule
  - imagine that the bowman's capsule is like a balloon that is inflated a little, this balloon will get closer to the glomerulus the glomerulus will start to push against the wall of the balloon so a part of the balloon will cover the glomerulus so it will be encased by the visceral layer of the bowman's capsule
  - what happens is that the blood will be filtered through the wall of the capillaries (glomeruli) and will enter the visceral layer of the balloon into a space called bowman's capsule space
  - after that it will flow into a tube that has a different shapes and goes into different directions
  - the blood that came to the glomerulus part of it will be filtered the other part will come out from the glomerulus and leave via the efferent arteriole and it will branch again to give rise to another capillary bed and here it will encircle the whole length of the tube along its way and this is called peritubular capillaries

- the peritubular capillaries again will coalesce into interlobular veins and these will drain into arcuate veins which will then drain into interlobar veins which will drain into segmental veins till it reaches the renal vein, and this is how the blood circulates from the renal artery back to renal vein (from all the nephron)
    - efferent arterioles→ peritubular capillaries →interlobular veins→ arcuate veins→ interlobar veins → segmental vein→ renal veins
        - if u notice, the names of the veins is the same as the arteries its just in reverse direction
- this organization of arteriole then capillary bed then arteriole then capillary bed Is called a portal system (normally its artery – arteriole – capillary- venule- vein)
- overall blood supply:
    - renal artery→segmental arteries→interlobar arteries→arcuate arteries→ interlobular arteries→afferent arterioles→glomeruli (capillaries) →efferent arterioles→ peritubular capillaries →interlobular veins→ arcuate veins→ interlobar veins → segmental vein→ renal veins



Major blood vessels of the kidney

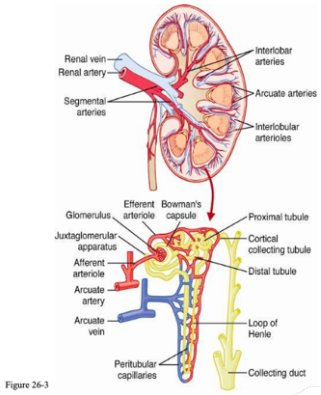
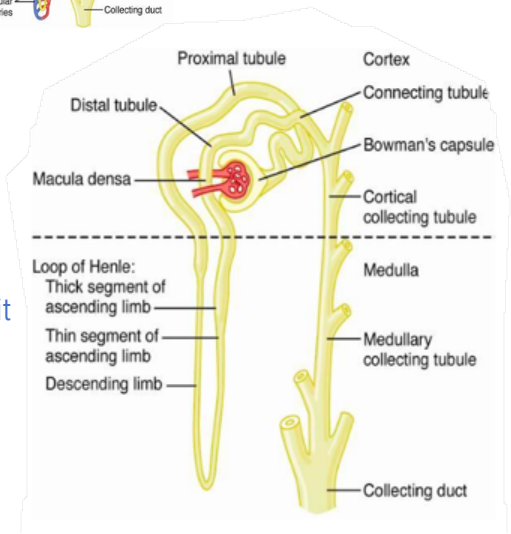


Figure 26-3

Components of the Nephron

- The nephron is composed of two main parts
    - The renal corpuscle
        - Is composed of the
            - Glomerulus
                - The afferent arteriole will enter it
                - The efferent arteriole will exit it
            - Bowmans capsule
    - The tubules
        - Proximal convoluted tubule
            - Lies in the cortex
            - Descend down to the medulla to form a loop called the loop Henle which has a descending and ascending part



- The ascending part will go to the cortical region to form the distal convoluted tubule
- Distal convoluted tubule
  - You can notice it passes between the afferent and efferent arterioles and it touches the afferent arterioles
  - Then it will leave as the connecting tubule
- The collecting tubules
  - In the beginning the connecting tube will connect to the collecting tubule in the cortex so its called the cortex collecting tubule then it will go the medulla
  - Once it goes to the medulla its called the medullary collecting tubule
- Collecting duct
  - many medullary collecting tubule will make a collecting duct
  - the urine that has been formed will drain outside the collecting duct via the renal papillae which will then excrete all the fluid into the renal calyxes and the renal pelvis

Types of Nephrons

- here in this picture we can see two types of nephrons and we can recognize that there are two blood supply organizations here
  - Cortical Nephrons
    - if you look at the first one (the one higher up towards the left) the one in the cortical region the main part of the nephron lies in the cortex, these form 85% of the total nephrons, a small part of the loop of Henle dips into the medulla by the majority of the structure is in the cortex
  - Juxtamedullary Nephrons
    - the second type of nephrons are called juxtamedullary nephrons (the one towards the right), there called the juxtamedullary nephron since it lies in between the cortex and the medulla and the loop of Henle extends deep into the medulla,
    - in the juxtamedullary nephrons there is a unique organization of the peritubular capillaries in which the arteries and veins lie parallel to each other which is important for concentrating urine , this is called vasa recta

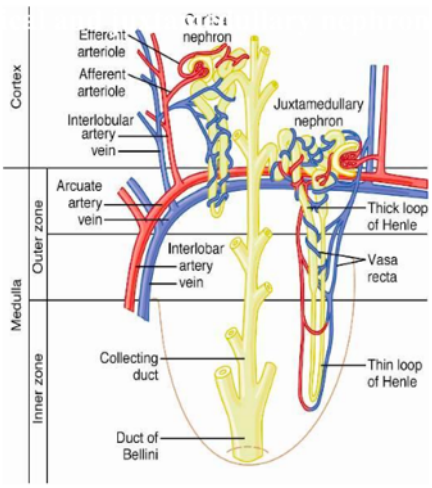
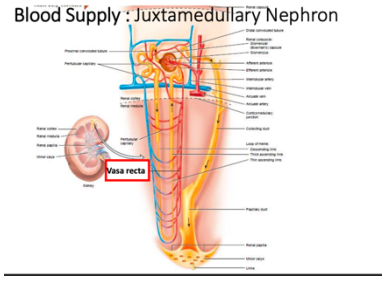
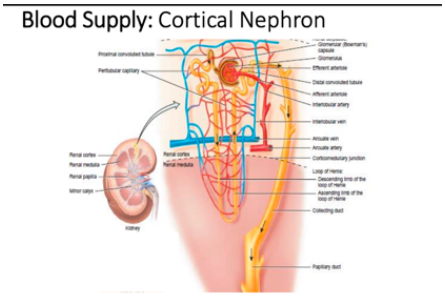


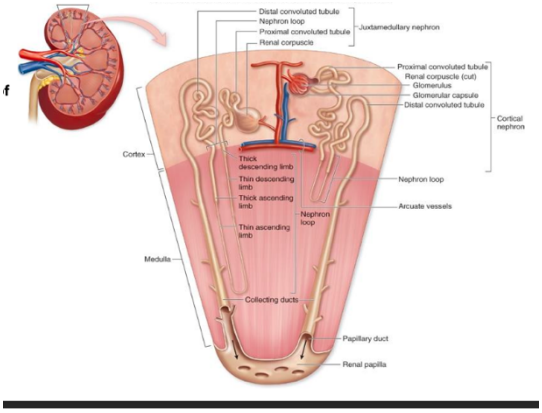
Figure 26-5





The Functional Unit of The Kidney?

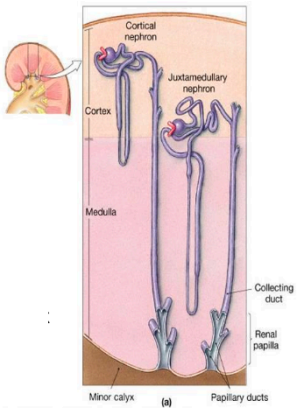
- Is the nephron.
- Each kidney is made up of 1 million of nephrons. (less with age!)
  - After the age of 40, about 10% of the nephrons will be lost every 10 years
  - So at the age of 80, 40% of the nephrons are lost
  - That doesn't mean the renal function is half of its normal function because the rest of the nephrons will compensate and adapt for the nephrons that have been lost
- 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)



Question

- Can a person live after nephrectomy, with one normal kidney?
  - Yes, If the remaining kidney is normal it can just do perfectly the whole iob

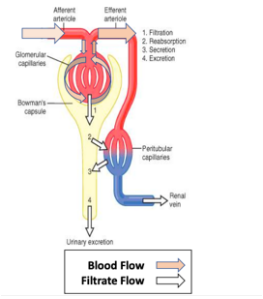
Types of Nephrons



- **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



- After the blood comes out of the glomerulus via the efferent arterioles and then will give rise to peritubular capillaries that will surround the system.
- In the peritubular capillaries – capillaries that surround the tubules- we see another process which is important in urine formation, reabsorption.
- Some of the constituents of the filtered fluid will come back to the circulation because they are important to the body, and we cannot eliminate everything has been filtered.
- Then we have secretion from the venous side of the peritubular capillaries where some of the waste products or unwanted acids get eliminated from the peritubular capillaries directly into the filtered fluid. So, secretion adds up to the filtered fluid. "it is faster to eliminate the substance via secretion rather than filtration
- Finally, everything left that is excreted is called urinary excretion.