UGS

Physiology

Doctor 2021

Sheet (1)

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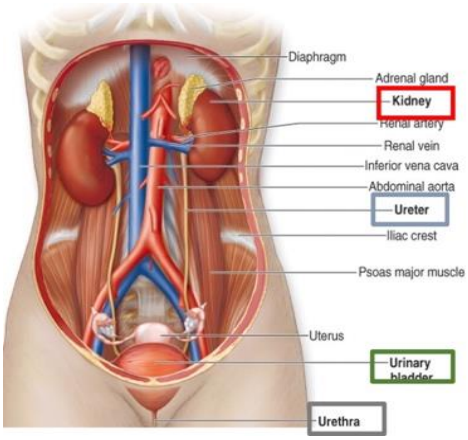
The Urinary System

Introductory video demonstrating the urinary system functions:
https://youtu.be/EhnRhfFLyOg?si=KXkJ6wxAzTrY1fuW



- **The Kidneys do most of the work of the urinary system, while other parts serve as passageways or storage organs.** Kidneys have the hilum which is an important structure that passes vessels into and out of the kidney. Blood comes to the kidneys via the renal artery which comes from the abdominal aorta then blood comes out in the renal vein into the inferior vena cava.
- **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** from body's metabolic activity **such as:**
    1. **Ammonia and urea (both formed when amino acids** & proteins **are broken down),**
    2. **Uric acid (formed when nucleic acids are broken down),**
    3. **Creatinine (from muscles,** from creatinine phosphate**),**
    4. **End products of hemoglobin metabolism** (bilirubin from RBC's turnover), **hormone metabolites foreign substances (e.g., drugs,** preservatives, **pesticides, & other chemicals ingested in the food).**

- **The blood is filtered** (urine is formed) **by the kidney through 3 processes called filtration** (acts as a strainer), **reabsorption** (bringing the good substances back to the system)**, and secretion.**
  The wastes leave the body as urine.

• **Conserves Valuable Nutrients.**

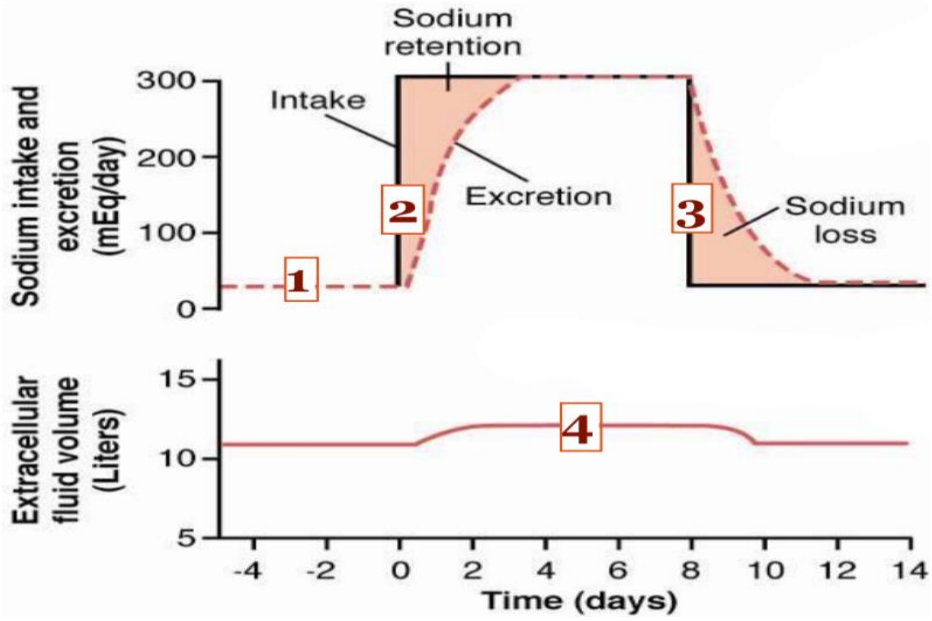
The urinary system ensures glucose, amino acids, fluids, electrolytes **and other valuable nutrients are not lost from the urine. Kidneys can also use glutamine to release glucose in gluconeogenesis** (when kidney have low glucose).

In the filtration process along with the waste products, some valuable nutrients are filtered which the urinary system brings back again to the blood by Reabsorption.

• **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 (adjusting the excretion rate from ECF).

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



See the image above, it shows how the kidney regulates the levels of the most important electrolyte in the body, which is sodium,

1. Normal intake of salt (≈30 milli equivalent/ day), with normal excretion (excretion rate= intake).
2. In increased sodium intake (*10), the kidney increases the sodium excretion, but this process is slow because it acts through hormones, it takes 2-3 days to be completed and by that time we will have sodium retention (because the excretion there was less than the intake).
3. The sodium intake returns to normal, but the excretion lags behind (gradual too) and it will be >intake for a while causing excretion to be more than intake and sodium is lost, but notice that the sodium loss EQUALS the sodium retention so they cancel each other, and the level of sodium will become normal again (perfect correction ✨).
4. Increase in extracellular fluid because the osmolarity (sodium intake). The increase in sodium level also leads to an increase in the extracellular fluid volume (water follows sodium).
   So, the kidney adjusts the electrolytes level and the ECF amount.
   The kidney can return the level of sodium to normal when the intake is high, but this is under one condition which is returning the intake rate to the normal level and then the kidney will do its job other than that the sodium retention will keep building up.

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

- **Regulates Blood Volume.**

  The urinary system regulates blood volume by:

  1. **Releasing renin** (secreted from the kidneys)**, a hormone that after a series of reactions eventually restricts salt and water loss at the kidneys** (by the RAS system).

     Decreased blood pressure-> renin-> angiotensin 2 (increases blood pressure).
  2. **Adjusting the volume of water lost in the urine.**

- **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.

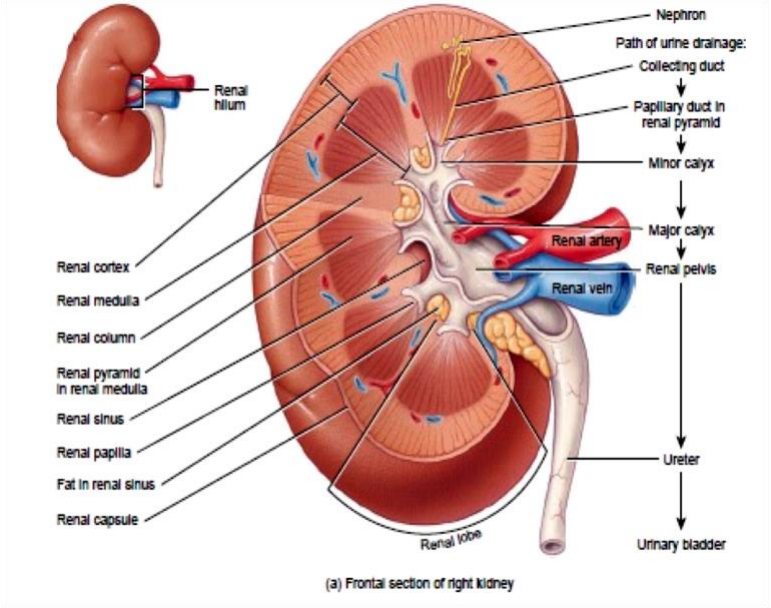
- **Produces and secretes hormones:** The kidney works as an endocrine organ
  - **Calcitriol: The active form of vitamin D** to get calcitriol from the kidney for bond density and Ca2+ absorption
  - **Renin: activates the renin-angiotensin-aldosterone system, thus regulating blood pressure regulation & Na+, K+ balance.**
  - **Prostaglandins/kinins: bradykinin = vasoactive, leading to modulation of renal blood flow & along with angiotensin II affect the systemic blood flow.** Prostaglandins are vasodilators that enhance the flow to the kidney and enhance its function, that why NSAIDs are contraindicated for renal disease patients.
  - **Erythropoietin: stimulates red blood cell formation by bone marrow.**

- **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.**

The kidney works as a passageway, storage, excretory and endocrine organ.

Kidney Structure



• A bean shaped organ.

• Composed of an outer layer, dense and lighter in color known as the **Renal cortex.**

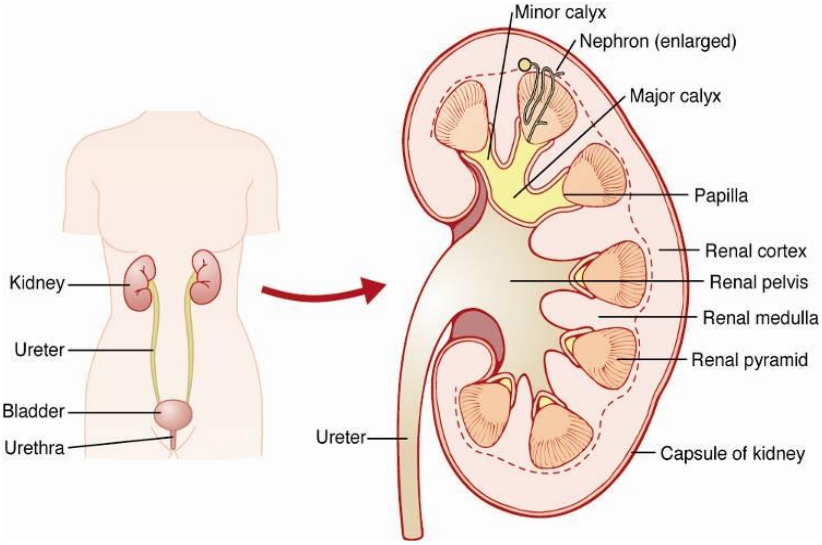
And an inner layer known as the **Renal medulla**, where we have pyramidal shapes (**Renal pyramids**) with **Renal columns** between them (connective tissue), Renal pyramids contain the **Nephrons** which filter blood then the filtered blood flows the through the **tubules** and then drains into **collecting tubules and ducts** till it reaches the tip known as **Renal papilla** then drain into structures known as **Minor calyces** then into **Major calyces**, then we will have a larger container of urine known as **Renal pelvis** which will empty all formed urine into the **Ureter** to be stored in the **Urinary bladder.**

• **The hilum** of the kidney is composed of the **Ureter**, **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** (connective tissue) separate renal pyramids.

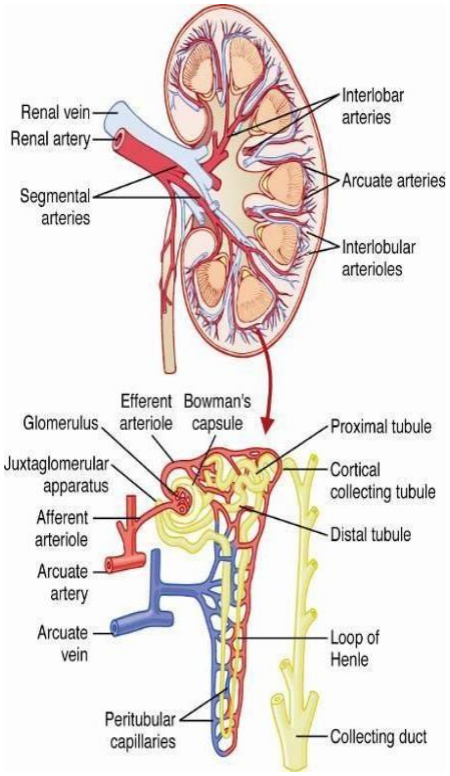
• **Renal capsule** is the covering connective tissue.

• **Nephrons are the functional units of kidney.**



Major blood vessels of the kidney

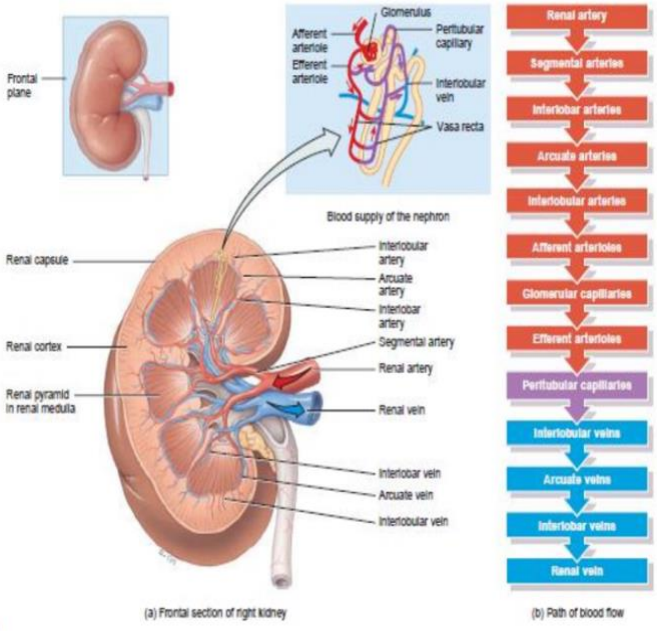
Blood supply is very important for the function of the kidney, because its function is filtration and for that we need a **high percentage of cardiac output ≈20%** for the kidneys solely and that blood isn't used for the kidneys' metabolism but for filtration.



Renal artery branch into **segmental artery** then becomes **interlobar artery** (between then columns) then it branches into **arcuate arteries** (horizontal arteries) which branch to give **interlobular arterioles** which then give rise to **afferent arterioles** then give rise to specialized capillary beds that are highly fenestrated (high filtration) called **glumerulous** as apart of the nephron.

The blood will be filtered through the walls of capillaries and enter the bowman's capsule space then flows through a tube system which have different shapes and directions.

Not all the blood that gets into the glomerulus get filtered, the blood that didn't get filtered leaves the glomerulus as an **efferent arteriole** which branch again and give rise to another capillary bed called **peritubular capillaries** that surrounds the tubular system of the nephron, then they will coalesce and become **venules,** which then become **arcuate veins** then **interlobar veins** until we reach the **renal vein.**



Afferent arteriole -> glomerulus -> efferent arteriole-> peritubular capillaries.

This (arteriole – capillaries – arterioles) system is an exception to the normal (arterioles – capillaries – veins) system. It is called the renal portal system (similar to the liver portal system).

Interactive website for the vascular system of the kidney: https://wisconline.blob.core.windows.net/learning-object/ap21518/SDMVNTBI/story.html

Structure of the nephron

• Each nephron is made up of the following:

❑ Renal Corpuscle

-Bowman's Capsule

-Glomerulus

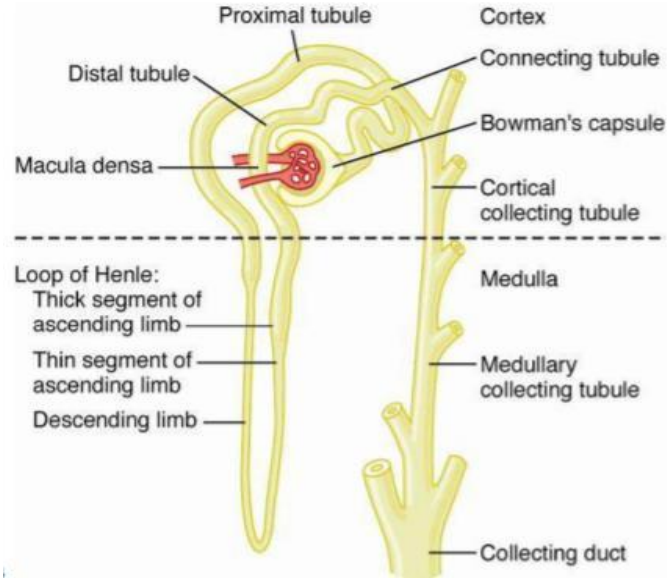
❑ Renal Tubules

-Proximal Convoluted Tubule (PCT)

-Loop of Henle (LH)

-Distal Convoluted Tubule (DCT)

-Collecting Duct (CD)

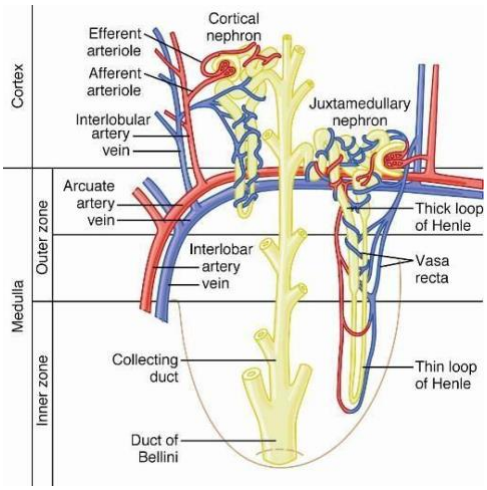


• **The nephron** is composed of two main pats: the renal corpuscle and tubular structure.

• The **Renal corpuscle** which is composed of a **glomerulus** touching the outer surface of the **bowman's capsule** (which is a ballon or cup like structure) and somehow bushing it inward, so that the glomerulus is incased with the bowman's capsule. Together the bowman's capsule and the glomerulus are called the renal corpuscle.

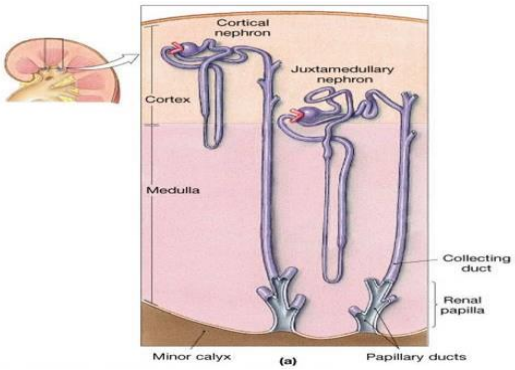
• The capsule is attached to a tubular system that starts very convoluted (متعرج) with the **proximal convoluted tubule (PCT)** which lies in the cortex, the next part of the tubular system looks a hairpin loop that descends down to the medulla forming the **loop of Henle (LH)** composed of a **thin descending segment (limb), thin ascending segment (limb), and thick ascending segment (limb).** The tubule gets again up and convoluted forming the **distal convoluted tubule (DCT)** which passes between the afferent and efferent arterioles and then connects to the **connecting tubule** and then to the **cortical collecting tubule** (in the cortex) then to the **medullary collecting tubule** (in the medulla) and at the end the **collecting duct** which collects so many connecting tubules together (a lot of nephrons) then the urine will flow into **the renal papilla** into the **renal calyces** and **pelvis.**

Types of Nephrons depending on the location of the nephron (2 blood supply organizations):



1. **Cortical nephrons**
   - **≈85% of all nephrons.**
   - **Are located in the cortex** (except a small part of loop of henle dips in the medulla).
   - **short Loop of Henle.**

2. **Juxtamedullary nephrons**
   - **Are deep in cortex closer (juxta = next to) the renal medulla** (on the borderline between the cortex and the medulla).
   - **The loops of Henle** (very long) **extend deep into the medulla (renal pyramids).**
   - **Ascending limb contains thin and thick ascending portions.**



• There is a different 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, and it extends deep to the medulla near the renal papilla.

• Juxtamedullary nephrons and vasa recta are very important in **concentrating urine** longer.

• The cortical nephron is short, most of it lies in the cortex.

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

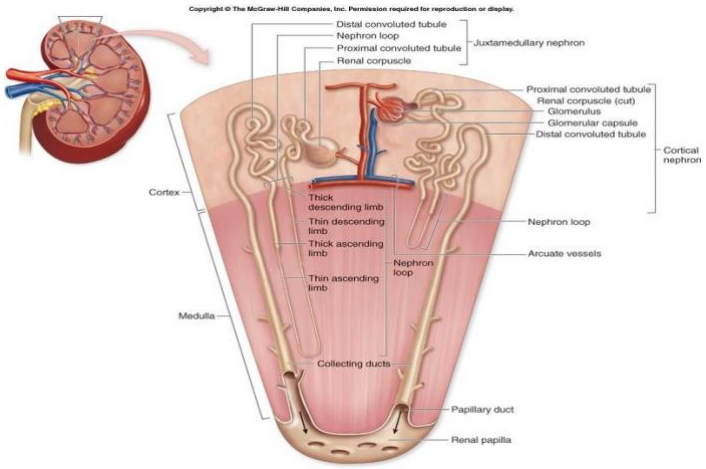
• **Each kidney is made up of 1 million of nephrons. (less with age!)** after 40, about 10% are lost every following 10 years. By the age of 80, 40% of nephrons are lost.

Losing 50% nephrons doesn't necessarily mean that the renal will be half of the normal, but the rest will compensate and work more efficiently, unless there is a disease in the remaining part.

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

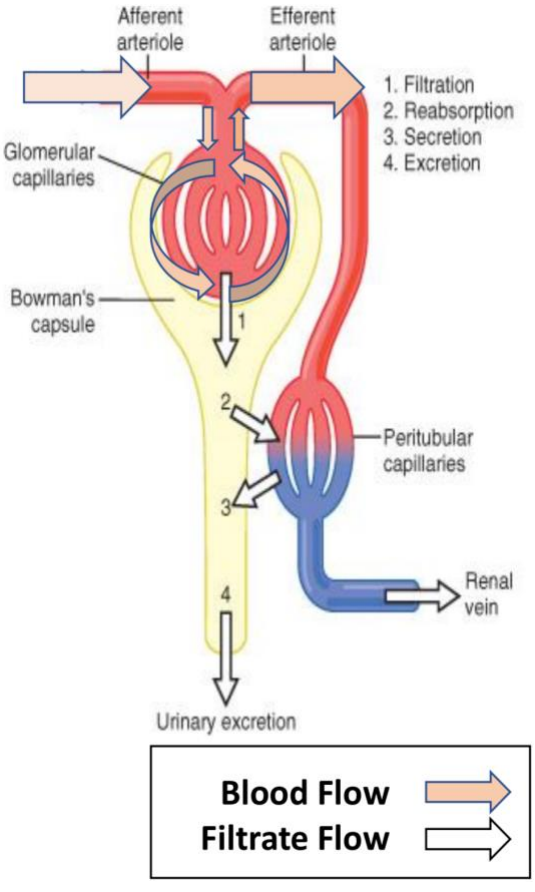
Nephron Blood Supply

- **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.**



Processes done by the kidney:

1. **Filtration**: afferent blood filtered to bowman's capsule (20% of the plasma flow), not filtered blood comes out in efferent arteriole to become peritubular capillaries that surround the tubes.
2. **Reabsorption**: some of the filtered fluids that we need will be reabsorbed back to the circulation.
3. **Secretion**: the waste and toxic substances are secreted from the blood by the peritubular capillaries to to the tubes with the filtered fluid (opposite direction to the reabsorption).
4. **Excretion:** the urine getting out of the body.
   (Excreted fluid= The filtered fluid – the reabsorbed fluid + the secreted fluid).



Notice the differences between the cortical and juxtamedullary blood supply that we talked about before.

Juxtamedullary: has vasa recta makes it more efficient to concentrate urine.