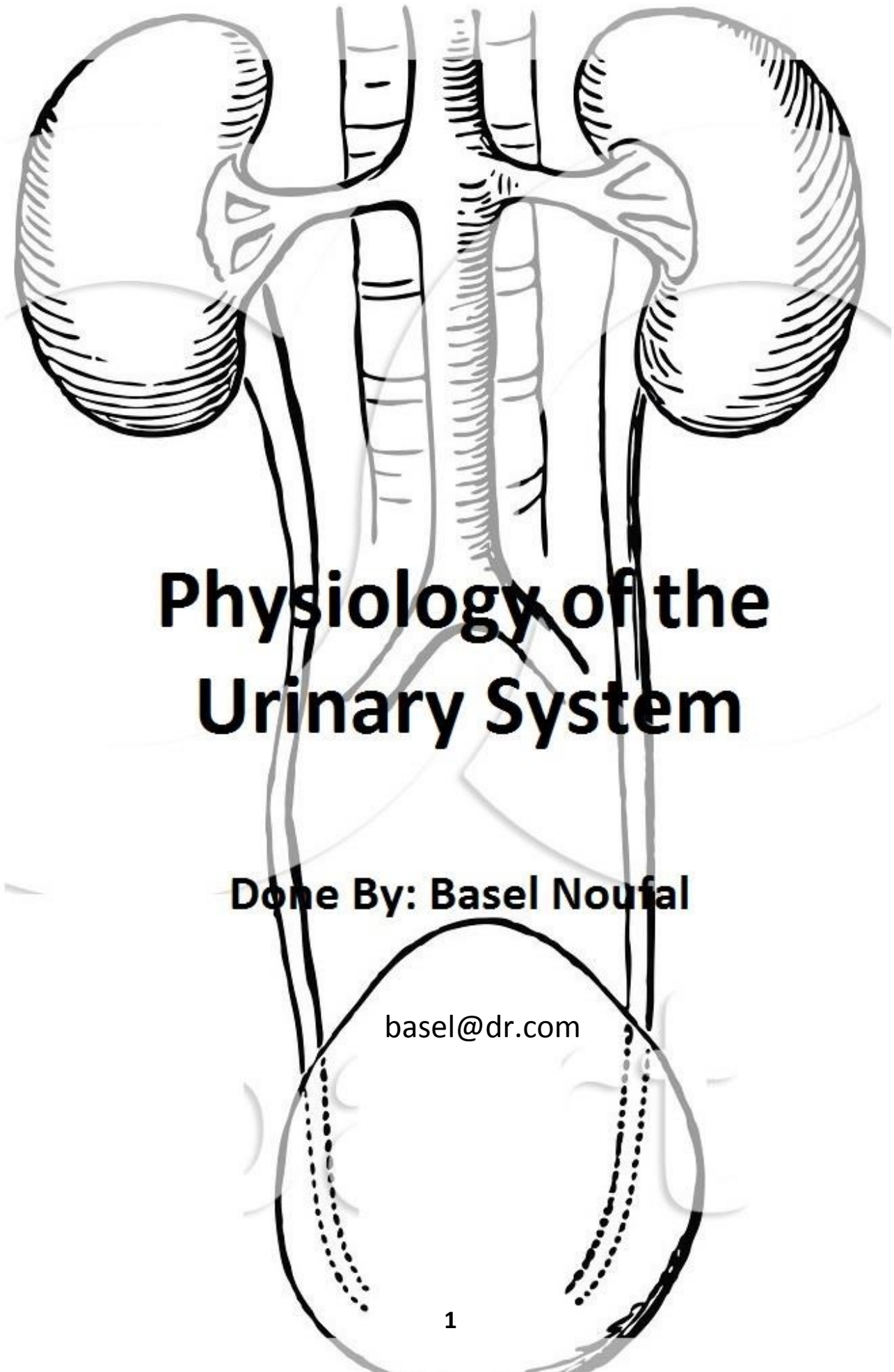

Physiology of the Urinary System

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Corrected and modified by Yanal A. Shafagoj MD. PhD

Textbook of medical physiology, by A.C. Guyton and John E, Hall•

If you prefer to study from textbook, I'll send you the outline

LECTURE (1)

Overview of the different Functions of The Kidneys And Renal Blood Flow

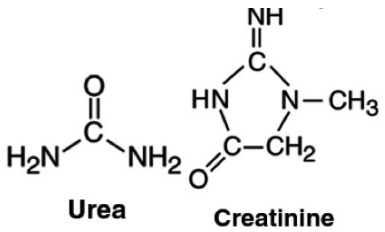
Multiple Functions of the kidney:

Uremia: toxic effects as wastes accumulate

✱ Remove waste products and foreign chemicals such as urea, creatinine, and uric acid, bilirubin, hydrogen etc. Those are endogenous substances. Renal failure (azotemia): means accumulation of nitrogenous wastes in blood. It means increase plasma levels of urea and nitrogen. The more the urea/creatinine levels in the plasma the more the loss of functioning nephrons. It is inversely proportional. less function of the kidney = more con of urea/ creatinine

↳ **The more the damage in the kidney, the more the con of urea/ creatinine in blood**

- ☐ Urea (from protein metabolism): proteins→amino acids →NH_2 removed →forms ammonia, liver convert it to urea
- ☐ Uric acid (from nucleic acid metabolism)
- ☐ Creatinine (from muscle metabolism)
- ☐ Bilirubin (from hemoglobin metabolism)
- ☐ Exogenous substances such as Pesticides, Food additives, Toxins, Drugs, and Detoxifies free radicals and drugs



Urea Creatinine

✞ Returns useful chemicals to blood such as Glucose and amino acids

↳ **Those substances are freely filtered but they are completely reabsorbed** / not lost in urine

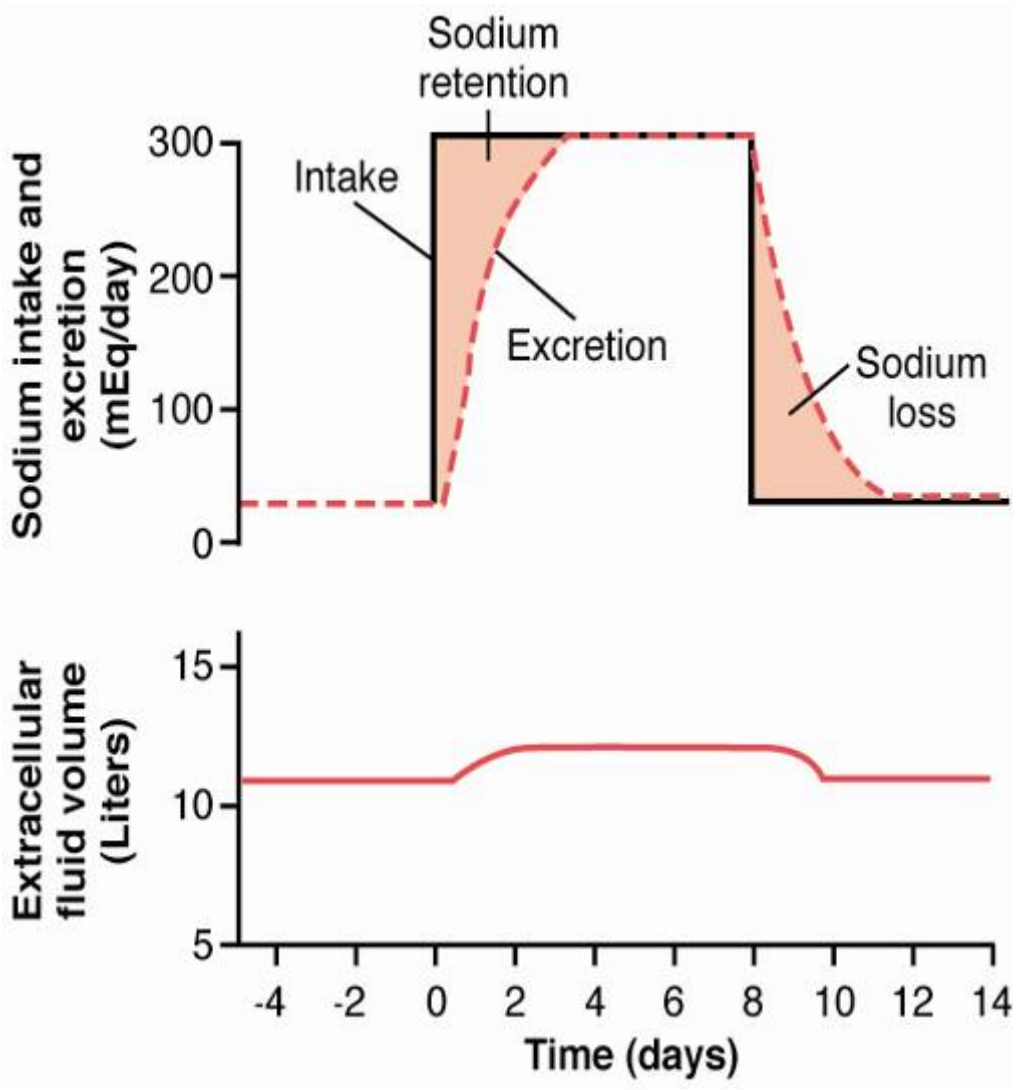
✞ Regulates blood volume and pressure (urine making makes blood volume less and thus, blood pressure less) ↳ **1.5 L of urine / day ➡️ if kidneys are not functioning, urine is not formed leading to hypervolemia + malignant increase in arterial BP (hypertension)**

✞ Regulates osmolarity of body fluids (dilution and concentration of urine)

✞ Secretes renin (renin- angiotensin-aldosterone system) and thus regulation of arterial blood pressure.

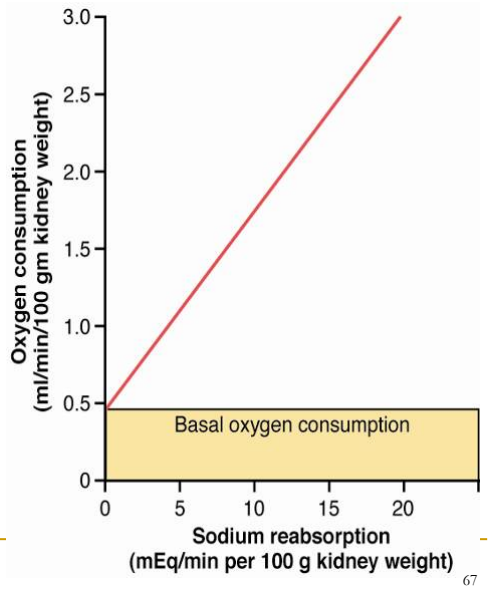
✞ Electrolyte balance (Na+, K+, Cl-, Ca++, P etc.) (Electrolyte homeostasis). I give an example of the Effect of increasing sodium intake 10-fold on urinary sodium excretion and extracellular fluid volume

If kidneys are not functioning this will result in hyperkalemia and cardiac arrhythmias



Effects of increasing sodium intake 10 folds (from 30 to 300 mEq/day) on urinary excretion and extracellular fluid volume. The shaded areas represent the net sodium retention or the net sodium loss, determined from the difference between sodium intake and sodium excretion.

Renal oxygen consumption and sodium reabsorption



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O2 consumption is directly related to Na+ reabsorption. If GFR is high —> Na+ reabsorption is high —> O2 consumption is high.
When GFR is severely depressed (acute RF) —> decrease need for O2 .. nothing to reabsorb

- Hormones metabolized and excreted by the kidney. Most peptide hormones (e.g. insulin, angiotensin II, etc.
- Secretes erythropoietin → (RBC production)…lack of EPO means anemia
- Convert 25-hydroxycholecalciferol into 1,25-dihydroxycholecalciferol (calcitriol), the most active form of vitamin D. Vitamin D_3 is important in calcium and phosphate metabolism
- Regulates H+ and HCO_3 and acid base balance…kidney failure leads to metabolic acidosis. Excrete acids. kidneys are the only means of excreting non-volatile acids. Regulate body fluid buffers (e.g. Bicarbonate)
- Gluconeogenesis: (conversion of non-sugar sources, particularly amino acids, into glucose at time of starvation (I don't mean Corona's time!)

Summary

Based on physiological functions of the kidney: In end-stage renal failure kidney failure will lead to death for many reasons, for example:

- Electrolyte imbalance

* K imbalance: lead to cardiac arrhythmias

Ca imbalance: affects bone (kidney is the major organ for Ca homeostasis)

- pH disturbance: metabolic acidosis

- Kidney secret erythropoietin→ therefore, kidney failure leads to anemia
- Kidney regulates the volume of blood: kidney failure→hypertension, malignant hypertension→pulmonary edema

Anatomy of the Kidney…go back to your histology lectures

✞ The kidney weighs 113-170 gm. **~ 125 gm**

✞ Renal artery arises as the fifth branch of the abdominal aorta. The renal artery arises from the aorta at the level of the second lumber vertebra. Because the aorta is to the left of the midline, the right renal artery is longer. The inferior vena cava lies to the right midline making the left renal vein two times longer than the right renal vein. For this reason it is better to take the donor left kidney (short artery, long vein) & place it in the right pelvis of the recipient. Multiple arteries & veins can supply the kidney.

PLEASE GO TO PAGE 9 NOW AND READ THE PARAGRAPH IN RED and return to this page

- Cortex : contain glomeruli ----->filtration **Outer 1 cm**
- Medulla : contain tubules ----->secretion and reabsorption **Renal columns, pyramids - papilla**
- Cortical atrophy : glomerulonephrits **Lobe of kidney: pyramid and its overlying cortex**
- Medullary atrophy : tubular nephritis

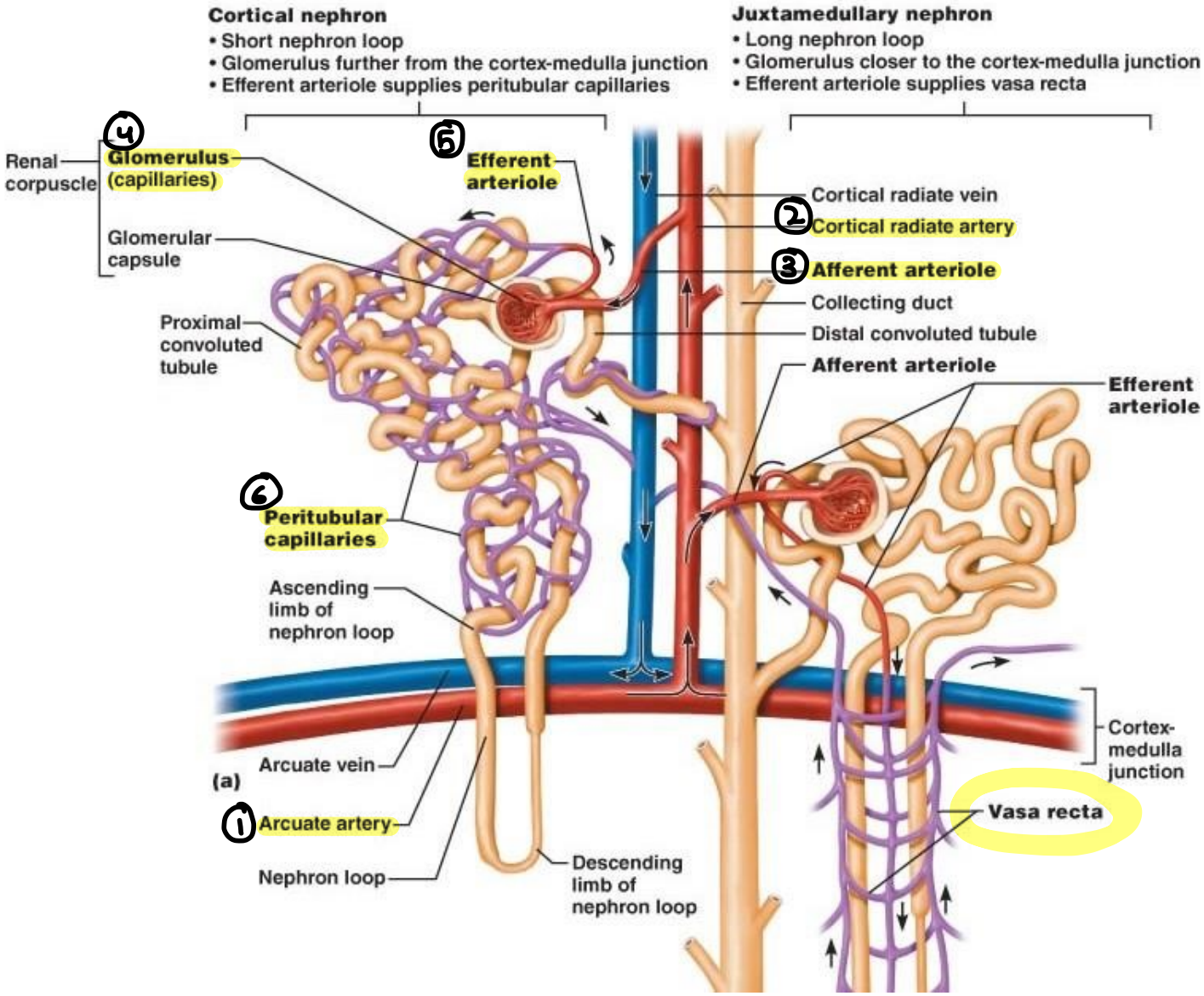
Cortical diseases come from the blood
Medullary diseases come from the bladder, urethra, ureter

- Cortical nephron have short loop of Henle (85 % of the nephrons)
- Juxta-medullary nephron: Having long loop of Henle and this is important in urine concentration (15-20% of the total nephrons).

If there is no juxta-medullary nephrons urine will not be concentrated

- In each kidney we have 1 million afferent arteriole & nephron.

Blood Supply of The Kidneys Structure and Function: **If you face any difference with your anatomy/histology course…consider the anatomy/histology lectures. I teach you physiology and not anatomy/histology**



✞ The renal artery (the fifth branch of the aorta) enters the kidney through its hilum and divides many times to form segmental arteries, interlobar arteries, arcuate arteries, interlobular arteries (cortical radiate arteries).

✞ Interlobular arteries divide again into many afferent arterioles.

✞ Transports arterial blood to the glomerular capillaries for filtration

Filtration is a passive process and it is non-specific (depend on size mainly, anything <70k will filter but with different degrees)

- Each afferent arteriole enters a glomerulus and divides to form the glomerular capillaries. The site for blood filtration which operates as a nonspecific filter; in that, it will filter both useful and non-useful material. The product of the glomerulus is called filtrate or ultrafiltrate indicating lack of proteins **In Bowman's capsule [Plasma - proteins (specifically the large ones)]**

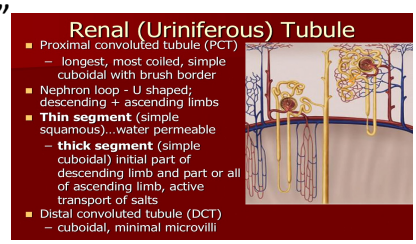
[Na+] in afferent arterioles = in the glomerular capillaries= in bowman's capsule
Same for glucose, K+, Ca++, aa

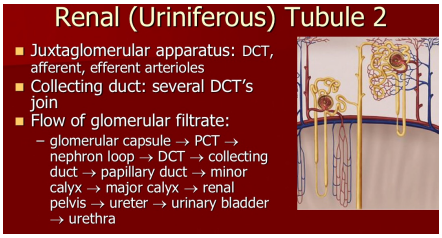
=in blood 140 mEq

- The capillaries converge again to form efferent arterioles.
- Efferent arterioles leave the glomerulus and divide, once again, to form peritubular capillaries. They Transport filtered blood from the glomerulus, through the peritubular capillaries and the vasa recta, and back to the kidney venous system
- Peritubular capillaries rejoin to form interlobular veins, arcuate veins, interlobar veins.
- Interlobar veins join to form the renal vein which leaves the kidney through its hilum.
- Note that the glomerular capillaries form the efferent arterioles, which divide again (instead of converging) to form other capillaries (two capillary beds). This is known as the portal circulation.
- Vasa recta are part of the peritubular capillaries that branch off the efferent arterioles of juxtamedullary nephrons (those nephrons closest to the medulla 15% of our nephrons are of this type). They enter the medulla, and surround the loop of Henle.

96% of blood is going to the cortex (red) while 4% are going to the medulla (white)

- Each kidney contains one million nephrons; each of which is around 5-6 cm long.
- The cortex contains the glomeruli of the nephrons, giving the cortex a granular appearance. In contrast, the medulla, which contains most of the length of the tubules, appears striated.
- **Bowman's Capsule**: A sac that encloses the glomerular capillaries and transfers filtrate from the glomerulus to the Proximal Convoluted Tubule (PCT).
- **Proximal Convoluted Tubule (PCT)**: A thick and most active segment of the nephron that reabsorbs most of the useful substances of the filtrate: sodium (65%), water (65%), bicarbonate (90%), chloride (50%), glucose (nearly 100%!) amino acids (≈100%), etc. The primary site for secretion (elimination) of drugs, waste and hydrogen ions
- **Descending Limb of the Loop of Henle:** Part of the counter current multiplier, freely permeable to water and relatively impermeable to solutes (salt particles), receives filtrate from the PCT, allows water to be absorbed and sends "salty" filtrate on the next segment. "Saves water and passes the salt"





✞ **Ascending Limb of the Loop of Henle**: Part of the counter current multiplier, impermeable to water and actively transports (reabsorbs) salt (NaCl) to the interstitial fluid of the pyramids in the medulla. "Saves salt and passes the water." the passing filtrate becomes dilute and the interstitium becomes hyperosmotic.

✞ **Distal Convoluted Tubule (DCT)**: Receives dilute fluid from the ascending limb of the Loop of Henle. Variably active portion of the nephron. When aldosterone hormone is present, sodium is reabsorbed and potassium is secreted. Water and chloride follow the sodium.

✞ **Collecting Duct**: Receives fluid from the DCT. Variably active portion of the Nephron. When antidiuretic hormone (ADH) is present, this duct becomes porous to water. Water from the collecting duct fluid then moves by osmosis into the "salty" (hyperosmotic) interstitium of the medulla. Therefore, it is the most important segment in the nephrone when water homeostasis is concerned. It is the last segment to save water for the b

✞ **Peritubular Capillaries.** Transport reabsorbed materials from the PCT and DCT into kidney veins and eventually back into the general circulation. Help complete the conservation process (reabsorption) that takes place in the kidney.

✞ What has been mentioned previously is from the anatomy/histology point of view. From the physiology point of view we can divide the nephron in two major parts only:

✞ **Functional Anatomy of the Kidney**

✞ Structure & function of the kidney are closely matched. The kidney is a combination of: We like to divide the nephrons into only two parts:

✞ 1. Ultrafiltation device (the glomerular apparatus).

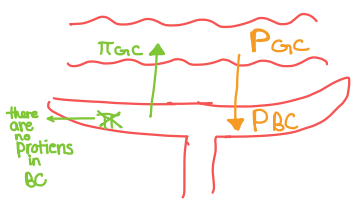
✞ 2. Epithelium (the rest of the nephron "the tubules"), which can modify this ultrafiltarte by two additional processes:

- Addition (secretion) or

- Removal (reabsorption) or both.

✞ Glomerular Filtration in the kidney is affected by Starling forces (Hydrostatic & Osmotic pressure…4 forces…from your CVS). In the kidney they are only three forces.

✞ Bowman's capsular space stands for the interstitium.



✞ We will come back again to Starling forces across glomerular membrane when we discuss with regulation of GFR later.

✞ Make sure to differentiate between: Filtration, secretion, reabsorption, and finally excretion

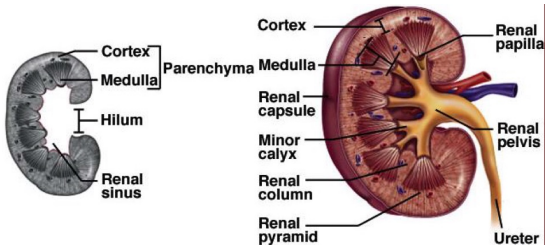
✞ **Excretion = Filtration - Reabsorption + Secretion**
in urine

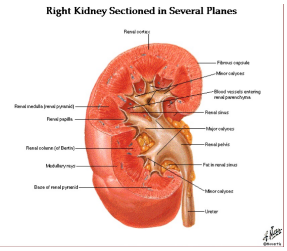
✞ Filtration : somewhat variable, not selective (except forproteins), averages 20% of renal plasma flow

✞ Reabsorption : highly variable and selective most electrolytes (e.g. Na^+, K^+, Cl^-) and nutritional substances (e.g. glucose) are almost completely reabsorbed; most waste products (e.g. urea) poorly reabsorbed

✞ Secretion : highly variable; important for rapidly excreting some waste products (e.g. $H^+$and K^+), foreign substances (including drugs), and toxins

✞



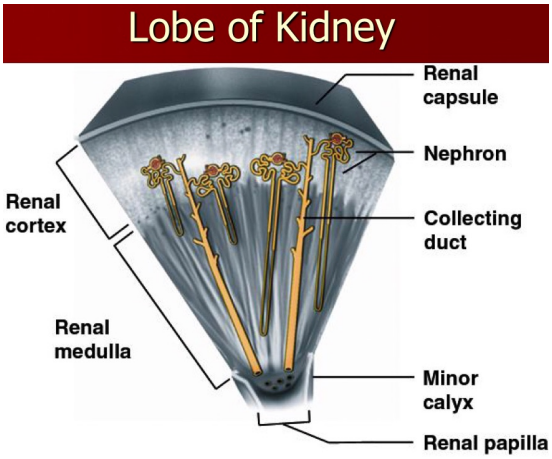


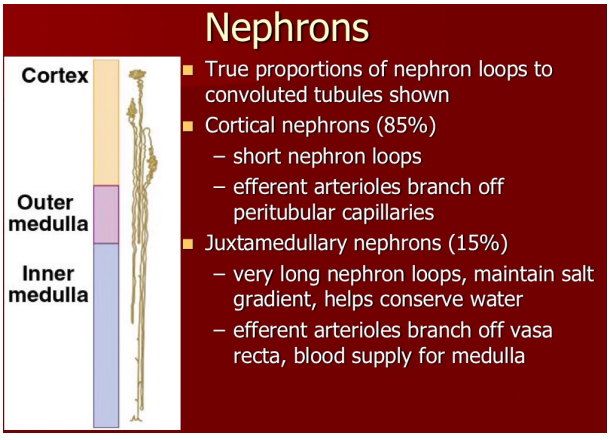
Each kidney has a cortex and medulla.
There are 2 million nephrons in both kidneys
1 million / kidney

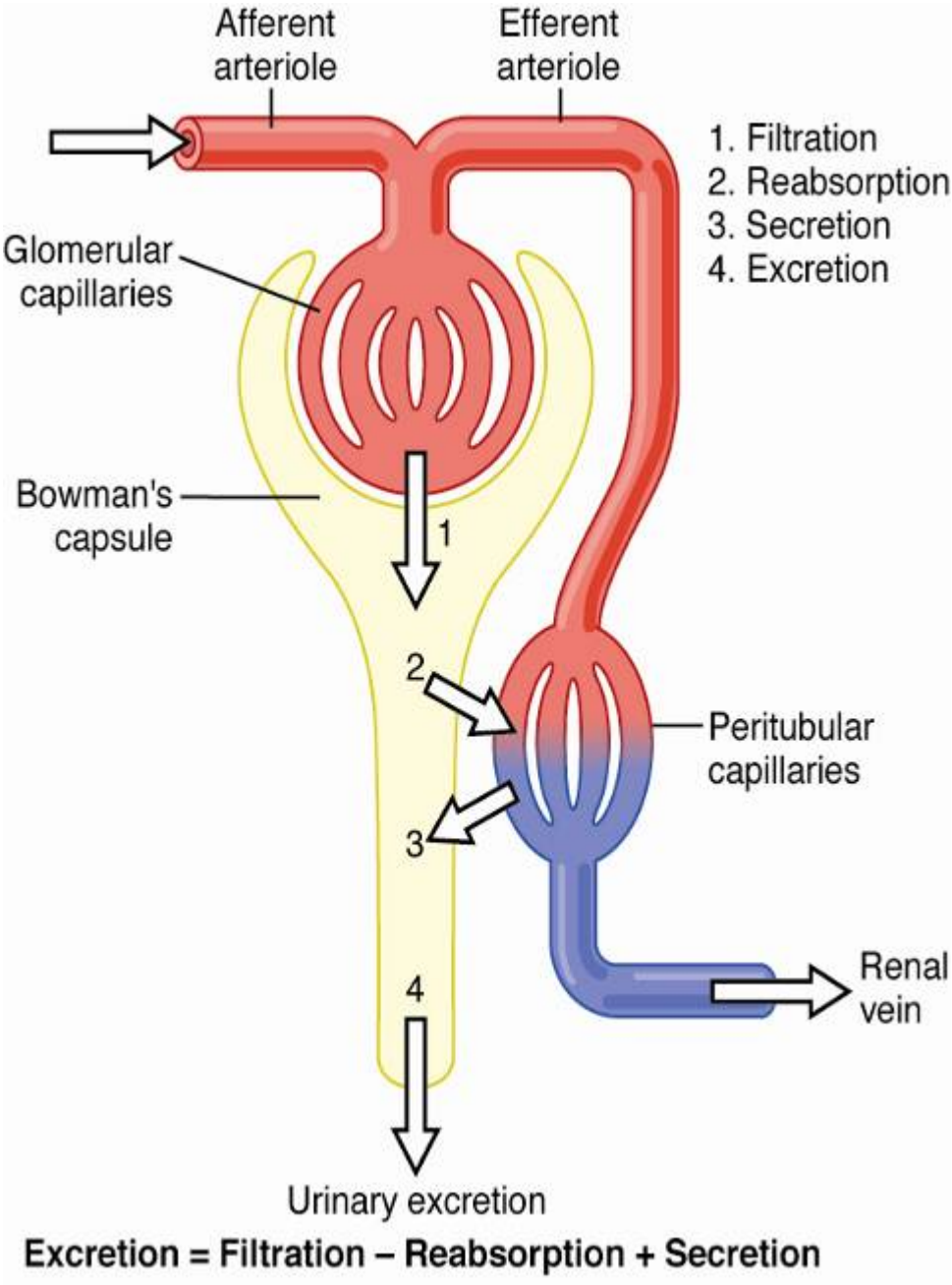
▶️ each nephron has a glomerulus (consist of 15 - 30 capillaries) present in the cortex of the kidney (granular in structure). This glomerulus give rise to tubules present in the medulla (striated in structure).

These nephrons differ in length (some are short and some are tall)
Small nephrons are found inside the cortex and called cortical nephrons (85%)
Long nephrons are near to the medulla and called juxtamedullary nephrons (15%)

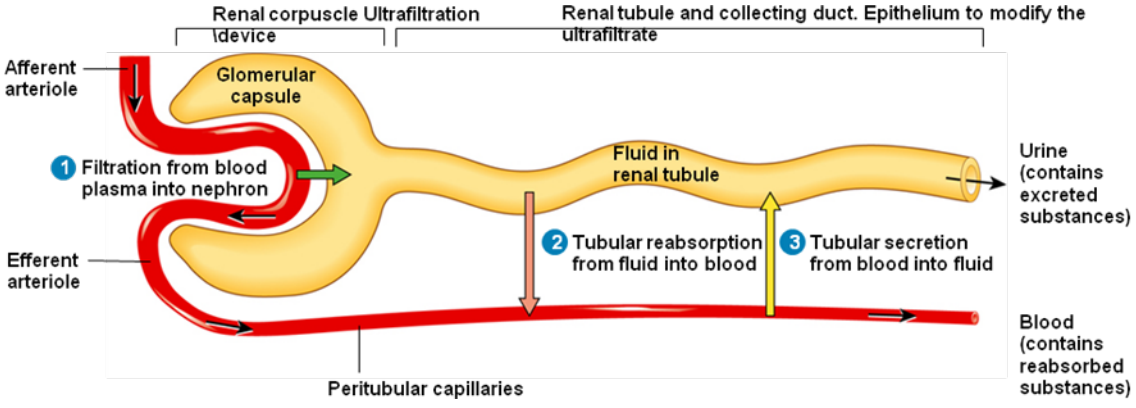
In the picture below you can find the collecting ducts that collect from more than one nephron —> minor calyx —> major calyx —> pelvis —> ureter







✞ **Excretion = Filtration – Reabsorption + Secretion**



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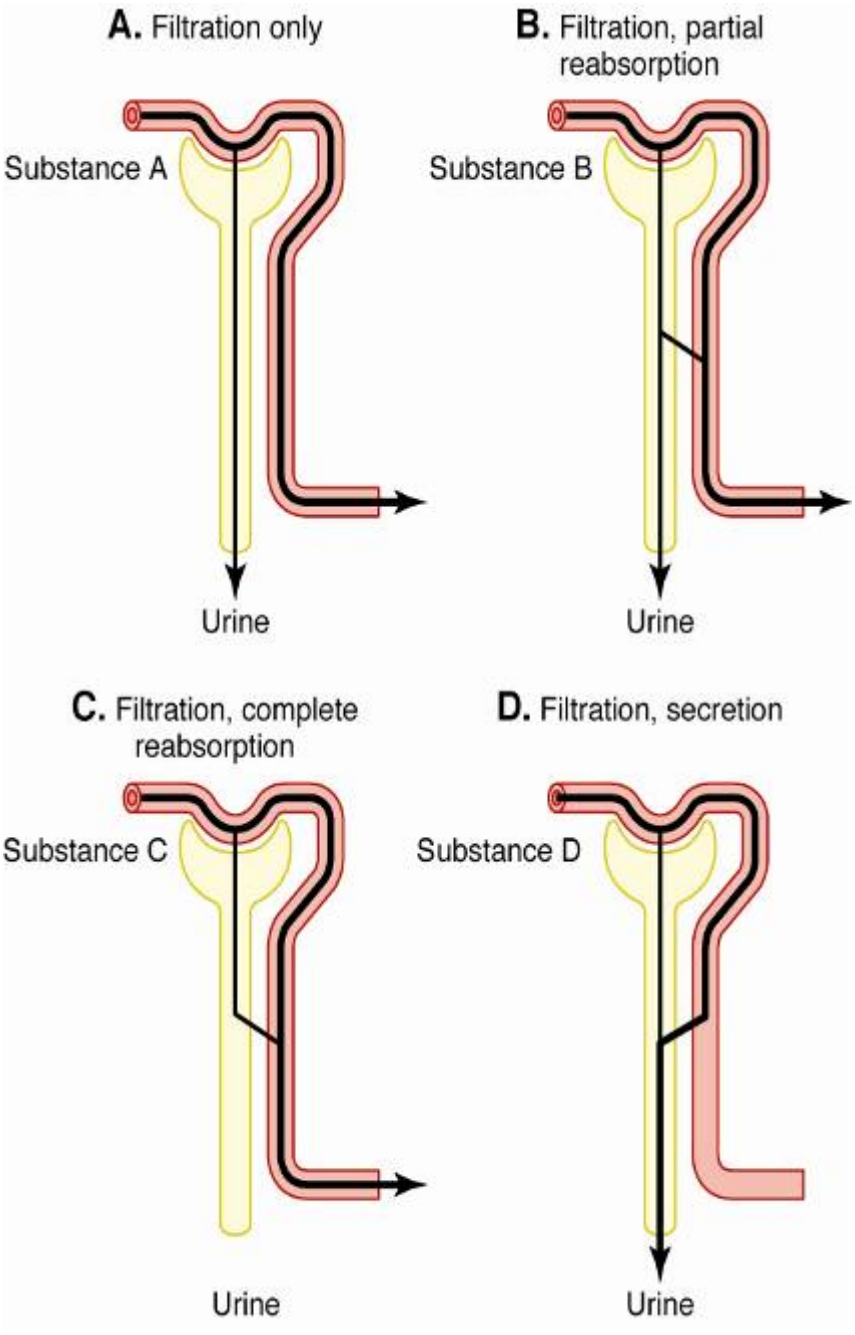

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It is true that anything < 70k can filter from the glomerular capillaries an exception is albumin which doesn't filter even though is wight is <70 k and that's because 1) it's weight is >60 k which makes it harder to filter compared to other smaller molecules 2) it is -ve charged | the endothelium of the capillaries, basement membrane and epithelium of nephrons are -ve charged too
If for any reason those structures lost their -ve charge, albumin will filter causing albumin-urea and hypoalbuminemia (leading to generalized edema)

Renal Handling of Water and Solutes

	Filtration	Reabsorption	Excretion
Water (liters/day)	180	178.5	1.5
Sodium (mmol/day)	25,560	25,410	150
Glucose (gm/day)	180	180	0
Creatinine (gm/day)	1.8	0	1.8

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- **Measuring Renal Blood Flow (RBF)** Not a routine clinical test

$$Cx = \left[\frac{U_x}{P_x}\right] * V \qquad RPF = \left[\frac{U_{PAH}}{P_{PAH}}\right] * V \qquad RBF = \left[\frac{RPF}{1 - Hct}\right]$$

If you understand the above 3 equations, you are in a good shape. But let's first understand what is RBF?

- RBF is defined as the volume of blood entering both kidneys per unit time. Can be expressed as the volume of blood which supplies each gram of the renal tissue per unit time.

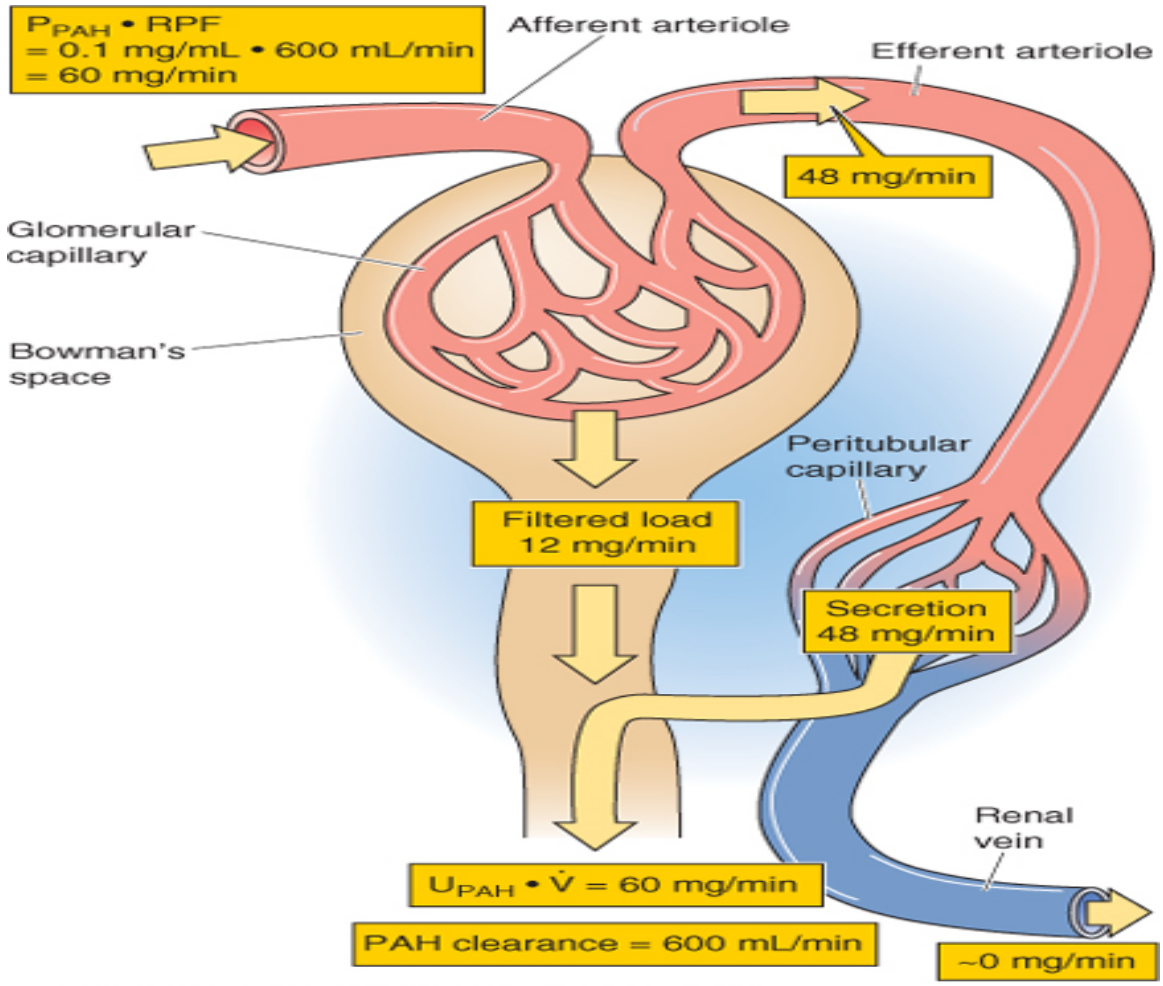
PLEASE GO TO PAGE 15+ 16 and study what is highlighted and written in red then return to this page 😄

- Through the above equation, the amount of the substance that enters the kidney has to be excreted in the urine, so we need a substance that is **totally excreted** by filtration and secretion without any reabsorption to the vein and these criteria are found in PAH. Its Renal vein concentration = 0

Completely remove (cleared) from the blood once it reaches the kidneys / once comes to peritubular capillaries it is completely secreted

para-aminohippuric acid

- هل فعلاً هذا الكلام ينطبق على هذه المادة أو على أي مادة أخرى في الكون؟



Boron & Boulpaep: Medical Physiology, 2nd Edition.

- The source of PAH in the urine:
    1. filtration 20% (12 mg/min)
    2. secretion 80% (48 mg/min)
    3. without any reabsorption
- RBF Averages **1.25 L/min** (1200-1250 ml/min) or **4.2 ml/g.min**. That is, **25%** of cardiac output.
- It is high compared to other organs (**0.03** and **0.5** ml/mg.min for skeletal muscles and brain, respectively…see the table below). Remember from your respiratory course, the carotid bodies receive the highest blood flow in our body: **20 ml/g.min**
- This high flow rate is consistent with the function of the kidneys, since it is a reconditioner organ (reconditioning the blood; meaning: change its composition). That is, the composition of the blood is significantly modified as it passes through the kidneys. The

blood doesn't go to the kidney simply to nourish it, but because the blood expect the kidney to change its cimposition.

- However, unlike other tissues, O_2 and nutrients concentrations do not decrease significantly as the blood leaves the kidneys. This is indicated by the arterio-venous a-vO_2 difference, which is relatively low (**1.4 ml/dl**) compared to **6** and **6.2** ml/dl for the skeletal muscles and the brain, respectively. Nevertheless, kidneys consume twice O2/per gm tissue as brain. In the heart (coronary circulation) the difference is 11 ml/dl (not much O2 reserve is left in the cardiac arteries…therefore, the heart is easily prone to ischemia).

- This O2 consumption in the kidney is directly related to Na^+ reabsorption. If GFR is high → Na^+ reabsorption is high→O2 consumption is high. When GFR is severely depressed (Acute kidney injury) → decrease need for O2

-

•Measuring Renal Blood Flow (RBF) and Renal Plasma Flow (RPF)

RPF: how much plasma enter both kidneys per minute

RBF is measured indirectly by using this equation: **RBF = RPF / (1-HCT).**

- If the RBF is 1200 ml/min and HCT is 0.45, then RPF ≈ 660 ml/min. Between 600-650 ml/min is normal. Any number you use is fine

- As mentioned earlier, we are gona use a substance X that is completely removed (cleaned) from the blood once it reaches the kidneys: i.e. Renal vein concentration of X = 0. i.e;. Actually there is no such substance. Simply because only 90% of RPF reach glomeruli (Effective RPF). 10 % of renal blood goes to nourish the kidney i.e. don't participate in the renal function…not filtered or secreted. Therefore,

- True RPF = effective RPF ÷ 0.9 . The extraction ratio of PAH =90%. (only 90% is excreted)

- $$Extraction E_{PAH} = \left[\frac{A_{PAH} - V_{PAH}}{A_{PAH}}\right] * 100\%$$

- So 585 ml/min (90%) is the effective RPF and 650 ml/min (100%) is called true or total tRPF

- The substance used commonly is the PAH (para-aminohippuric acid)

- If RPF=650 ml/min

- 125 is filtered (GFR).

- How much is the filtration fraction? Can you calculate the filtration fraction?
- FF= GFR / Renal plasma flow=20% filtered and 80% secreted.
- .
- 525 ml leaves through efferent arteriole and go to peritubular capillaries.
- 1 ml/min is the urine output. One ml out of 125 ml is excreted s urine (0.8%)

- Maintaining the RPF within its normal range is very important; even a decrease in the RPF for a short time causes the ions to accumulate in the narrow loops of Henle forming crystals and thus occluding the tubule→ total loss of kidney function. What you should remember is: in case of shock (bleeding) we care the most about the kidney. If RBF decreases →→acute kidney injury.

- Practically, the **RPF** is measured first. Then, the **RBF** can be mathematically obtained, as discussed earlier.

Cardiac output is about 5L that are going to: kidney, muscles, brain, GIT, others (each is supplied approximately with 1 L). kidneys are supplied by ~ 1250 ml which will supply the kidneys with O2 but mainly it will change the composition of the blood => kidneys are considered reconditioner organs)

Remember:

- The a-vO_2, or the arterio-venous oxygen difference, is the difference in oxygen concentration between arterial and venous blood. It is used as an indication of how much oxygen is extracted from the blood capillaries.

It will be very low (minimal) for the kidneys that is because kidneys are interested more with changing the combustion of blood than extracting oxygen

- 55% of the blood is plasma (92% water and 8% solutes and suspended particles) while 45% is formed of suspended cells (mainly RBCs). This 45% is termed hematocrit (HCT) or packed cell volume (PCV).

Renal plasma flow (RPF) for both kidneys = 1250 * 55%= 650 ml/ min | here we aren't concerned with PCV because they don't filter

Glomerular filtration per min is GFR = 125 ml/ min => filtration fraction = 125/ 650 = 20% → GFR/RPF×100%
80% of RPF goes back into the efferent arterioles

Tissue	Blood flow (ml/g/min)	A-V difference (Vol %)	Flow ml/min	O_2 ml/
Heart	0.8	11 = heart will utilize most of the O2 coming to it	250	27
Brain	0.5	6.2 (25-30% Extraction)	750-900	
Skeletal Muscle	0.03	6	1200	70

This indicates that whenever coronary blood flow decreases, this leads to ischemia
However if the blood supply to the kidneys decreases it won't probably lead to ischemia (= no cellular damage). [if the decrease is huge it may lead to ischemia]. But don't forget that kidneys basically work on blood, so if blood isn't reaching the kidneys, they won't work.

Liver	0.6	3.4 Reconditioner organ		
SKIN	0.1			
Kidney	4.2	1.4	1250	18
Carotid bodies	20	0.5	0.6	

****RBF = 1250 ml/ min || urinary output = 1 ml/ min = 60 ml/ h = 1440 ml/ d ~ 1.5 ml / day || what returns from RBF = 1250 - 1 ml/ min = 1249 ml/ min**

Don't worry…it is not expected from you to recall these numbers…relax•

Renal Clearance (if you understand the concept of clearance, you master 50% of the renal physiology)

- Defined as the volume of plasma completely cleared of a substance per unit time.
- Refers to the volume of plasma necessary to supply the amount of a substance excreted in urine per unit time.
- C_x: Is volume of plasma/min provides X for excretion/min.
- Unit of clearance: Volume/time
- Excretion rate is the amount of a substance excreted in urine per unit time. It is calculated by multiplying urine flow rate by urine concentration of the substance (U_s x V).
- Urine flow rate (urine output) is the volume of urine excreted per unit time.
- To understand the concept of clearance, assume that 60 grams of a substance were dissolved in a glass containing 1 liter of water, and after a minute, half of the substance (30 grams) were removed from the solution. This is equivalent to having two glasses of water; one contains 60 grams dissolved in 0.5 liter of water, and the second contains 0.5 liter of water without any of the substance. This means that the clearance of the substance is 0.5 L/min (i.e., 0.5 liter can be isolated after a minute keeping the amount of the substance in the other 0.5 liter the same).

Another example:

- **If we have 650 ml plasma with specific amount of X, after leaving the kidney all of the plasma was cleaned from X. 100% of the 650 ml/min. Then C_x= 650 ml/min**
- **We have 650 ml plasma with specific amount of Z, after leaving the kidney we find half of the amount of Z in the renal vein. Clearance will be 50% of the 650 C_Z= 325 ml/min**

"Use the Law of Conservation of Mass":

- **Amount excreted in the urine/min = Amount provided for excretion (by artery)/min**
- Amount Excreted of X (mg/min) = Urine output (V) * Ux = Amount provided for excretion (mg/min) = RPF * Px P=plasma
- *Conditions must be met before using "x" as RPF marker: "X" does not accumulate, made, or catabolized by the kidney*
-

Renal clearance can be stated mathematically as follows:

$$C_s \times P_s = V \times U_s$$ where:

C_s: clearance rate of the substance. P_s: Plasma concentration of the substance.
V: urine flow rate (urine output). U_s: Urine concentration of the substance.

- If the plasma concentration of a substance is 1 mg/ml, and 1 ml of urine were collected within a minute. The concentration of the substance in the urine was 70 mg/ml. Then C_s = 1 ml/min x 70 mg /ml / 1 mg/ml = 70 ml/min.

•RPF Measurement

Amount excreted = amount filtered + amount secreted – amount reabsorbed. A special substance (paraaminohippuric acid or **PAH**) is almost completely excreted. Therefore, since all the blood entering the kidneys will be cleared of PAH, the clearance of PAH is the RPF. Thus, using the clearance equation, and substituting RPF for C_s:

$$RPF \times P_s = V \times U_s$$

- PAH is only **90%** excreted and not 100%. This, in fact, is the maximum percentage achievable because **10%** of blood entering the kidneys does not participate in urine formation. Rather, it supplies the renal tissue with the necessary oxygen and nutrients.

Thus, 90% of blood entering the kidneys (true renal plasma flow) is the **effective renal plasma flow**.

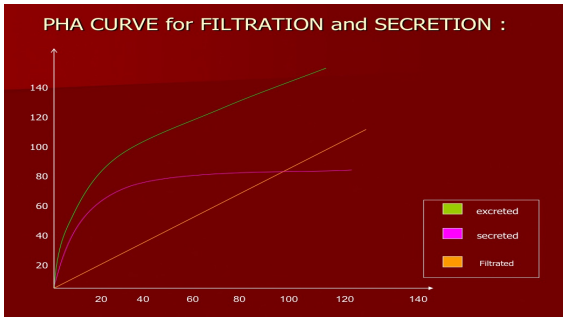
- PAH clearance was measured to be 585 ml/min, which is the effective renal plasma flow. Thus, the RPF = 585/0.9, or around 650 ml/min.

- Filtration is a passive process (i.e., no transporters are needed to move substances (including water) across capillaries membranes.
- What determines the amount filtrated is the permeability of the membrane for the substance, its concentration gradient across the membrane and the time the substance remains in the glomerular capillaries. *This implies that as the concentration gradient increases, filtration rate increases linearly and unlimitedly*.
- Secretion, on the other hand, is an active process (i.e., transporter-dependent). Therefore, increasing the concentration gradient increases secretion rate *only to a limit.* Above the limit, further increase in concentration gradient does not increase secretion rate *because all the transporters have been occupied (i.e., saturated).* The transport rate at which secretion (or reabsorption, as explained later) rate reaches is maximum is designated T_{max} (transport maximum).

- The T_{max} of PAH transporters is **80 mg/min**. Therefore, to measure the RPF accurately, PAH reaching the peritubular tubules per minute must be used in small concentration (much less than 80 mg/min). Otherwise, less than 90% would be excreted, and thus the RPF would be underestimated.

- In fact, even an amount just less than 80 mg (e.g., 75 mg) would result in inaccurate RPF estimation because although not all the transporters would be occupied, *the probability for each PAH molecules to bind to a transporter would be exceedingly low*, and those PAH molecules which escape and do not bind to their transporter would be returned to the venous blood rather than excreted leading to underestimation of RPF.

- Therefore, with very low plasma concentration, most of the PAH in the urine (80%) is secreted actively by the transporters in the tubules. Only 20% is filtered and not reabsorbed. However, with much higher plasma concentrations only 80 mg/ml is excreted in the urine by secretion, and the rest is the filtered PAH. In this case, PAH clearance would approach the GFR rather than RPF.



- The difference between predicted excretion rate for PAH (assuming all PAH molecules bind to their transporter) and actual excretion rate is called splay. It is high at high PAH concentrations (i.e., just less than T_{max}) and approaches zero at lower concentrations.
- **Note:**the last two points will be further explained when glucose reabsorption is discussed.

✞ **Example:** If the plasma concentration of a substance is **2500 mg/ml** and **60%**of the substance passing through the kidneys is filtered and **10%** secreted while **20%** reabsorbed. Assuming infinitive T_{max} for the substance transporters, calculate the clearance and the RPF (per minute) given that during the next 24 hours, **720 ml** of urine were collected, and the substance concentration in urine was **100 mg/ml**.

- V = 720 ml/day = 0.5 ml/min Us = 100 mg/ml Pc = 2500 mg/ml
- Cs = (V x U) / Ps = 0.5 x 100 / 2500 = 0.02 ml/min
- Excreted = 60 + 10 -20 = 50%
- Since T_{max} is much higher than the concentration of the substance reaching peritubular capillaries, the splay phenomenon does not affect the accuracy of the calculated RPF. Thus, RPF = 0.02 / 0.50 = 0.04 ml/min. (half of the RPF was cleared)

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Lecture (2 and 3)

Glomerular Filtration Rate

Is the first step in urine formation.

By the way: Filtered load of a substance "x" : is how much of "x" is being filtered/minute.

Large amounts of plasma diffusing passively into Bowman's capsule.

✞ What is the difference between filtration and diffusion?

✞ Filtration is a bulk flow of fluids with the dissolved solutes. It is driven by the pressure gradient across the membrane.

✞ Diffusion is the movement of molecule by molecule. They cross the membrane based on concentration gradient (glucose) or down their electrochemical gradient (electrolytes). The composition of the filtrate is essentially similar to that of the plasma. However,