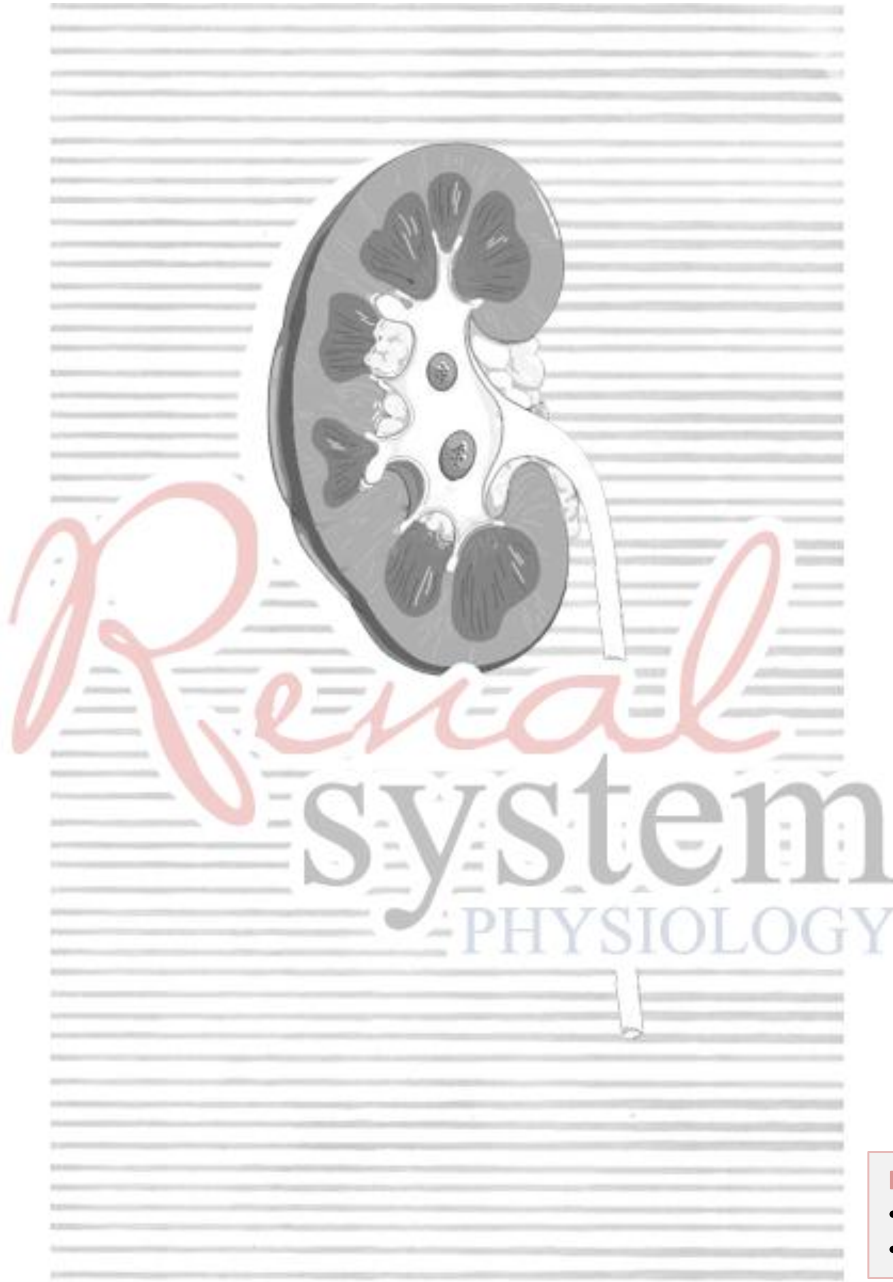


- Very important
- Extra information

References :
- GUYTON AND HALL 12th edition
- LINDA 5th edition

* Guyton corners, anything that is colored with grey is EXTRA explanation

3. Renal Clearance

Objectives :

- Describe the concept of renal plasma clearance.
- Use the formula for measuring renal clearance.
- Use clearance principles for inulin, creatinine etc. for determination of GFR.
- Explain why it is easier for a physician to use creatinine clearance Instead of Inulin for the estimation of GFR.
- Describe glucose and urea clearance.
- Explain why we use of PAH clearance for measuring renal blood flow.

Contact us : Physiology435@gmail.com

Concepts of Clearance

Definition	**The clearance value of a certain substance :** *[means the volume of plasma which is cleared from this substance in urine each minute].*
Calculation	**The formula is :** $C = \frac{U \times V}{P}$ **C =** Renal clearance (ml/min) **(V) =** Volume of urine (ml /min). *(urine flow rate)* **(U) =** Conc. of the substance in urine (mg/ml). **(P) =** Conc. of the substance in plasma/serum (mg/ml). **UXV =** Excretion rate of substance
Plasma Clearance Tests	**The properties of any exogenous substance *used in* plasma *clearance tests* *are:*** 1. Stays in the plasma (does not enter the RBC's). 2. Does not affect the renal functions. 3. Not metabolized by the kidney. 4. Easily measured in plasma & urine. 5. Non toxic.
Assume	If the substance is freely filtered at the glomeruli and is not reabsorbed, secreted or metabolized in the nephron *(such as Inulin)*, then: Amount filtered per minute = Amount excreted per minute $[sub]_{plasma}$ x GFR = $[sub]_{urine}$ x urine flow rate

Concepts of Clearance

- **Amount of substance excreted =** (filtered – reabsorbed + secreted)

$$\{ U_x V = GFR \times P_x \pm T_x \}$$

[Before starting the lecture, we have to know] :

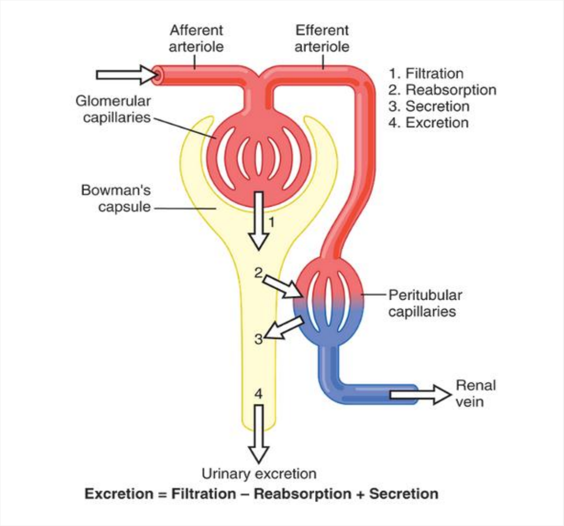
- **What does clearance mean ?**
  .كمية الدم التي تم تنظيفها من مادة معينة

- Increased Filtration = increased Excretion
- Increased Reabsorption = Decreased Excretion
- Increased Secretion = Increased Excretion

- **What does the clearance depend on?**

1) Clearance of a substance depend on excretion. If excretion is high = clearance will be high
2) Conc. of substance in plasma, if its high = clearance will be *less*
3) Clearance of a substance depend on it GFR and tubular activities.

- **Guyton corner :**



Basic kidney processes that determine the composition of the urine. Urinary excretion rate of a substance is equal to the rate at which the substance is filtered minus its reabsorption rate plus the rate at which it is secreted from the peritubular capillary blood into the tubules.

EXTRA

Term	Equation	Units
Clearance rate (C_s)	$C_s = \frac{U_s \times \dot{V}}{P_s}$	ml/min
Glomerular filtration rate (GFR)	$GFR = \frac{U_{inulin} \times \dot{V}}{P_{inulin}}$	
Clearance ratio	$\text{Clearance ratio} = \frac{C_s}{C_{inulin}}$	None
Effective renal plasma flow (ERPF)	$ERPF = C_{PAH} = \frac{U_{PAH} \times \dot{V}}{P_{PAH}}$	ml/min
Renal plasma flow (RPF)	$RPF = \frac{C_{PAH}}{E_{PAH}} = \frac{(U_{PAH} \times \dot{V}/P_{PAH})}{(P_{PAH} - V_{PAH})/P_{PAH}} = \frac{U_{PAH} \times \dot{V}}{P_{PAH} - V_{PAH}}$	ml/min
Renal blood flow (RBF)	$RBF = \frac{RPF}{1 - \text{Hematocrit}}$	ml/min
Excretion rate	$\text{Excretion rate} = U_s \times \dot{V}$	mg/min, mmol/min, or mEq/min
Reabsorption rate	$\text{Reabsorption rate} = \text{Filtered load} - \text{Excretion rate} = (GFR \times P_s) - (U_s \times \dot{V})$	mg/min, mmol/min, or mEq/min
Secretion rate	$\text{Secretion rate} = \text{Excretion rate} - \text{Filtered load}$	mg/min, mmol/min, or mEq/min

Table 27-4 Use of Clearance to Quantify Kidney Function

- ## Guyton corner :

C_s is the clearance rate of a substance s, P_s is the plasma concentration of the substance, U_s is the urine concentration of that substance, and V is the urine flow rate. Rearranging this equation, clearance can be expressed as :

$$C_s = \frac{U_s \times V}{P_s}$$

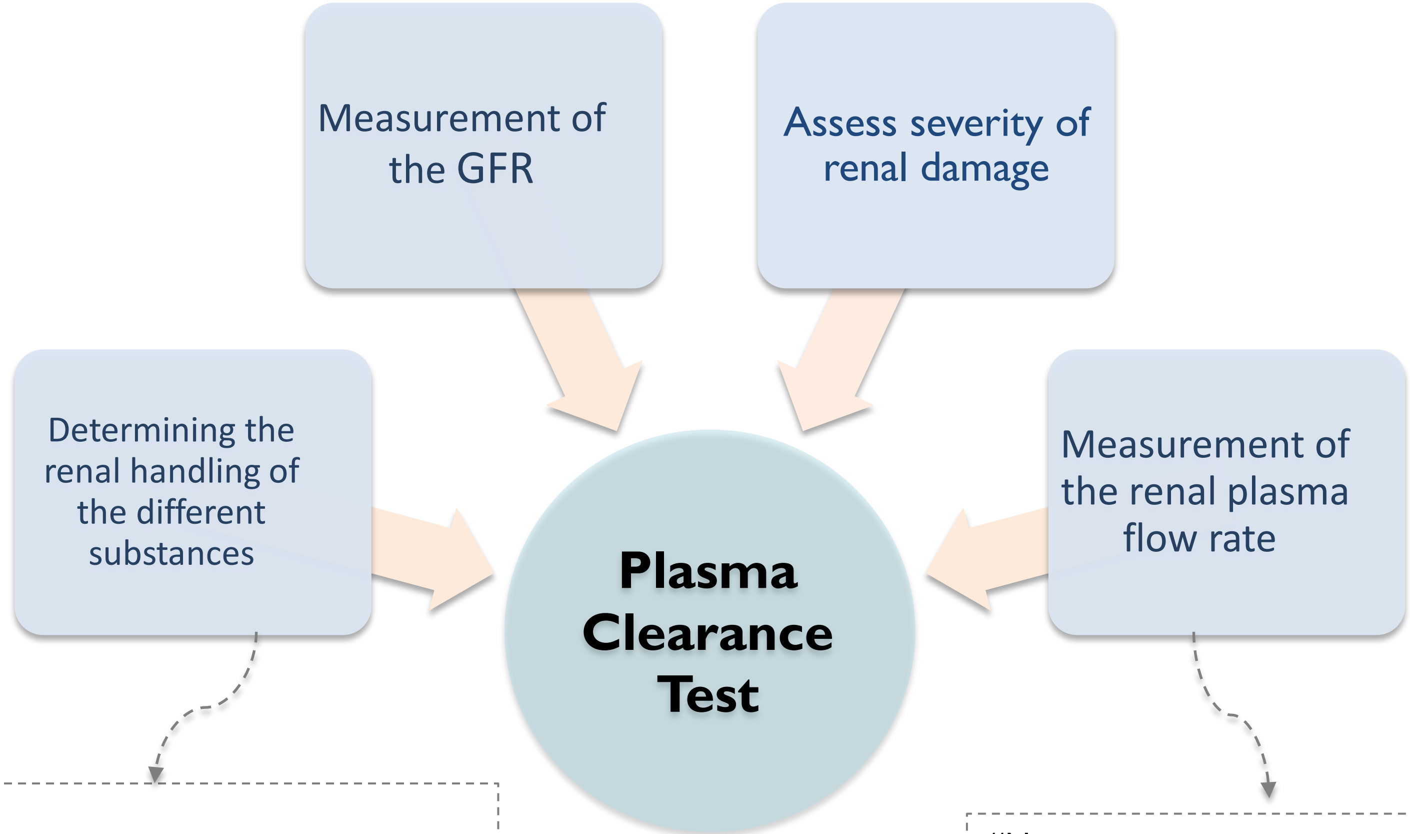
Thus, renal clearance of a substance is calculated from the urinary excretion rate ($U_s \times V$) of that substance divided by its plasma concentration.

- ## Guyton corner :

The rates at which different substances are "cleared" from the plasma provide a useful way of quantitating the effectiveness with which the kidneys excrete various substances (Table 27-4). By definition, the *renal clearance of a substance is the volume of plasma that is completely cleared of the substance by the kidneys per unit time*.
This concept is somewhat abstract because there is no single volume of plasma that is *completely* cleared of a substance. However, renal clearance provides a useful way of quantifying the excretory function of the kidneys and, as discussed later, can be used to quantify the rate at which blood flows through the kidneys, as well as the basic functions of the kidneys: glomerular filtration, tubular reabsorption, and tubular secretion.
To illustrate the clearance principle, consider the following example: If the plasma passing through the kidneys contains 1 milligram of a substance in each milliliter and if 1 milligram of this substance is also excreted into the urine each minute, then 1 ml/min of the plasma is "cleared" of the substance. Thus, clearance refers to the volume of plasma that would be necessary to supply the amount of substance excreted in the urine per unit time.

Importance of renal clearance

- **Plasma clearance tests can be used for:**



#Note:
whether or not the substance is reabsorbed or secreted by the renal tubules

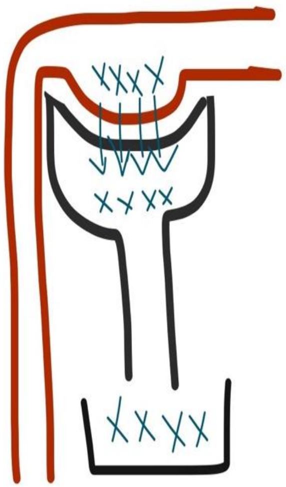
#Note:
From there we can calculate the renal blood flow rate.

EXTRA NOTES

May help you to understand the next slides

الجسم يتعامل مع أي مادة عن طريق أربعة طرق :

1



- **clearance : 100%**
- **amount filtered = amount excreted**
- **0% reabsorbed**
- **0% secreted**

اذا المادة ما صار لها سيكريشن ولا اكسكريشن راح تساويGFR
لأنها زي ما دخلت طلعت. نتكلم عن الكمية اما بالنسبة للتركيز راح يختلف. ليش؟ مثلا لو اعطينا بنت كوب موية كبير وبنت ثانية كوب موية صغير وحطينا ملعقة سكر في كل الكوبين، بيكون تركيز السكر في الصغير اعلى من الكبير. فالكمية نفسها لكن التركيز غير

- example of substance that help us indicate GFR: inulin&creatinine
- we cannot say that inulin is completely cleared; because there is still some amount of it that is unfiltered. We say that the "amount filtered" is completely cleared.

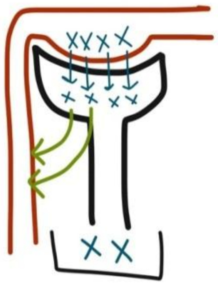
بما ان مادة انيولين تاخذ وقت في حساب كليرنس لاننا تحتاج حقن المريض بها وانتظار Steady state
صار كريتينين هو المادة البديلة لإنيولين لانه موجود بالجسم . صحيح انه يصير له سيكريشن ١٠٪ بس تبين لهم أنهم لما يحسبون كميته بالدم يكون تركيزه أعلى من الحقيقي بقليل فبالتالي راح يعطينا نتيجة طبيعية والسيكريشن ماراح يؤثر بالنتيجة

This figure is similar to that drawn by Dr.manan in the lecture. Thanks Munira :)

EXTRA NOTES

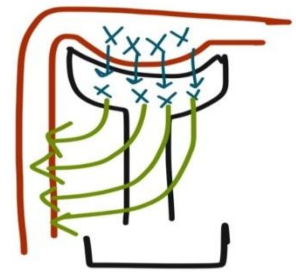
May help you to understand the next slides

2



- **Partially reabsorbed**
- **Partially cleared**
- **Example : Na+ ions , urea**

3



- **100% reabsorbed**
- **0% clearance**
- **Example: glucose**

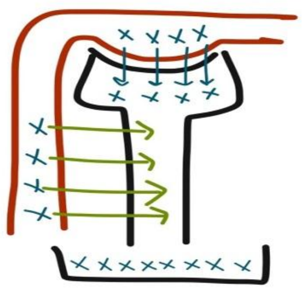
الجلكوز له خاصية glucose max
بمعنى إنه له حد في الـ reabsorptionإذا تعداه يصير excretionللجلكوز
مثلاً لو كان الجلكوز ١٠٠ راح يصير له كله reabsorption
لكن لو وصل تركيزه ٢٠٠ هنا يبدأ الجلكوز يطلع مع البول لأنه تعدى الكمية الي ممكن تستوعبها الـ carriers
عملية الـ Reabsorption تستمر حتى يوصل تركيز الجلكوز لـ350
هنا تتوقف العملية بشكل تام.
السبب وراء استمرارها حتى بعد ما تتعدى الـ Threshold
هو لأن كل نيفرون مختلفة عن الثانية من ناحية قدرتها على إعادة الامتصاص. بعضها توقف عند 200 والبعض تستمر لحد 350ثم تتوقف
الجلكوز الطبيعي في الدم ما يتعدى 200

These figures are similar to those drawn by Dr.manan in the lecture. Thanks Munira :)

EXTRA NOTES

May help you to understand the next slides

4



clearance of substance that is completely filtered and secreted = 0% reabsorption
Ex: para aminohippuric acid

amount entered the nephron = amount excreted + 10%
(كمية قليلة من المادة 10% تبقى في الدم ومايحصل لها سكريشن فلذلك نضيف 10% عشان ما تأثر في النتيجة)

بمعنى لما يصير للـ 20% من المادة المارة فيلتريشن يروح باقي الـ 80% للـ peritubular arterioles
ويحصله سيكريشن فيكون الدم تخلص تماماً من هذه المادة.

- **What can we indicate from this substance?**

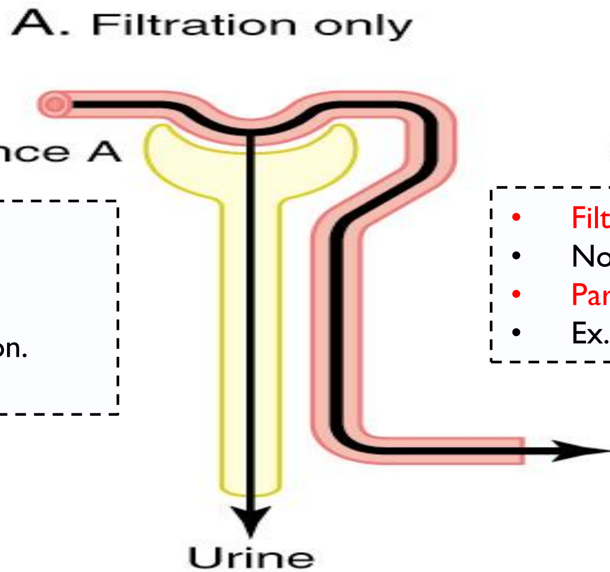
By measuring the clearance of the substance we know the renal plasma flow. Therefore we can calculate the whole blood flow by :

RPF (560) = 55%

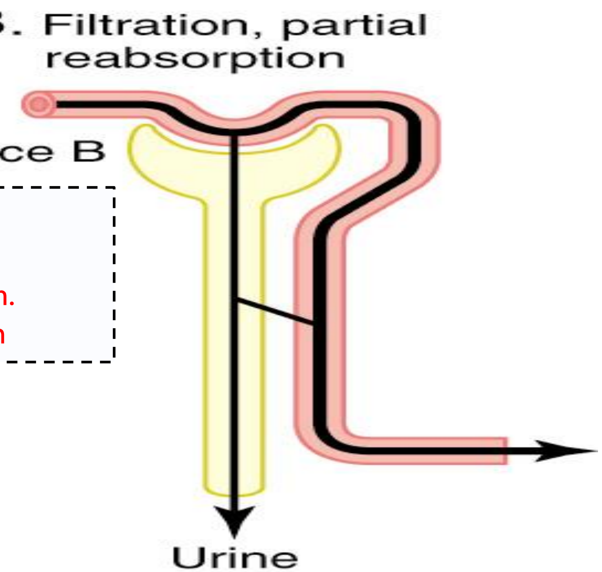
RBF = 100%

RBF= 560 x 100 / 55 = 1018 ml/min

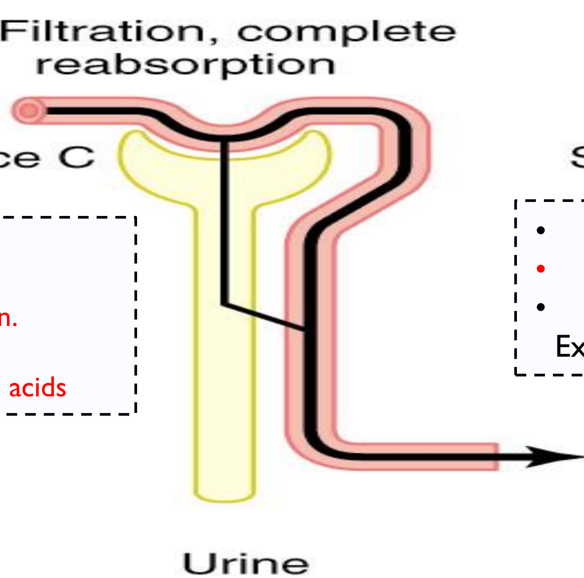
This figure is similar to that drawn by Dr.manan in the lecture. Thanks Munira :)



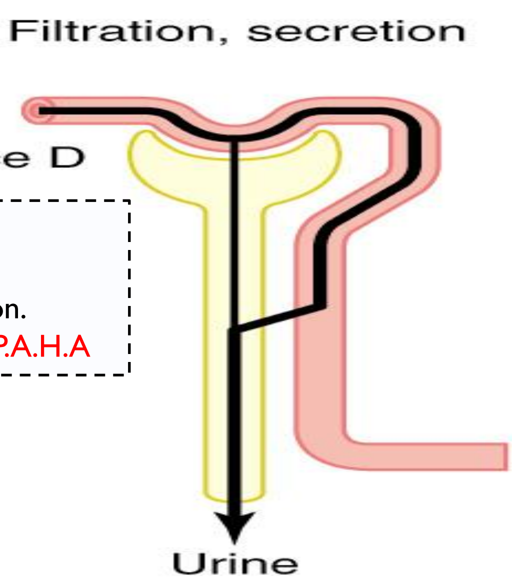
- Filtration only.
- No secretion.
- No reabsorption.
- Complete excretion.
- Ex. : Inulin



- Filtration.
- No secretion.
- Partial reabsorption.
- Ex. : Urea & Sodium



- Filtration.
- No secretion.
- Complete reabsorption.
- No excretion.
- Ex. : Glucose & Amino acids



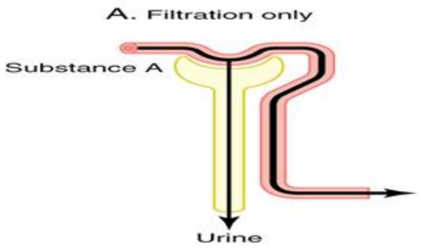
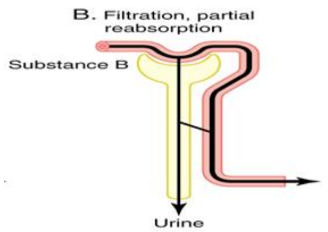
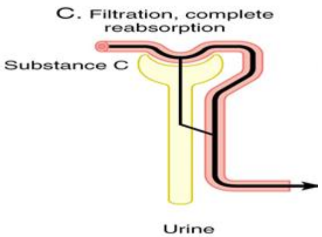
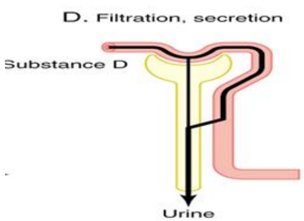
- Filtration.
- Secretion.
- No reabsorption.

Ex. : Creatinine & P.A.H.A

Every single word in this slide is VERY IMPORTANT !

P.A.H.A (Para-Aminohippuric acid)

Summary of the previous slide

	• Filtration only. • No secretion. • No reabsorption. • Complete excretion. • Ex. : Inulin
	• Filtration. • No secretion. • Partial reabsorption. • Ex. : Urea & Sodium
	• Filtration. • No secretion. • Complete reabsorption. • No excretion. • Ex. : Glucose & Amino acids
	• Filtration. • Secretion. • No reabsorption. • Ex. : Creatinine & P.A.H.A

- **Guyton corner :**

Figure 26-10 shows the renal handling of four hypothetical substances. The substance shown in **panel A** is freely filtered by the glomerular capillaries but is neither reabsorbed nor secreted. Therefore, its excretion rate is equal to the rate at which it was filtered. Certain waste products in the body, such as creatinine, are handled by the kidneys in this manner, allowing excretion of essentially all that is filtered.

In **panel B**, the substance is freely filtered but is also partly reabsorbed from the tubules back into the blood. Therefore, the rate of urinary excretion is less than the rate of filtration at the glomerular capillaries. In this case, the excretion rate is calculated as the filtration rate minus the reabsorption rate. This is typical for many of the electrolytes of the body such as sodium and chloride ions.

In **panel C**, the substance is freely filtered at the glomerular capillaries but is not excreted into the urine because all the filtered substance is reabsorbed from the tubules back into the blood. This pattern occurs for some of the nutritional substances in the blood, such as amino acids and glucose, allowing them to be conserved in the body fluids.

The substance in **panel D** is freely filtered at the glomerular capillaries and is not reabsorbed, but additional quantities of this substance are secreted from the peritubular capillary blood into the renal tubules. This pattern often occurs for organic acids and bases, permitting them to be rapidly cleared from the blood and excreted in large amounts in the urine. The excretion rate in this case is calculated as filtration rate plus tubular secretion rate.For each substance in the plasma, a particular combination of filtration, reabsorption, and secretion occurs. The rate at which the substance is excreted in the urine depends on the relative rates of these three basic renal processes.

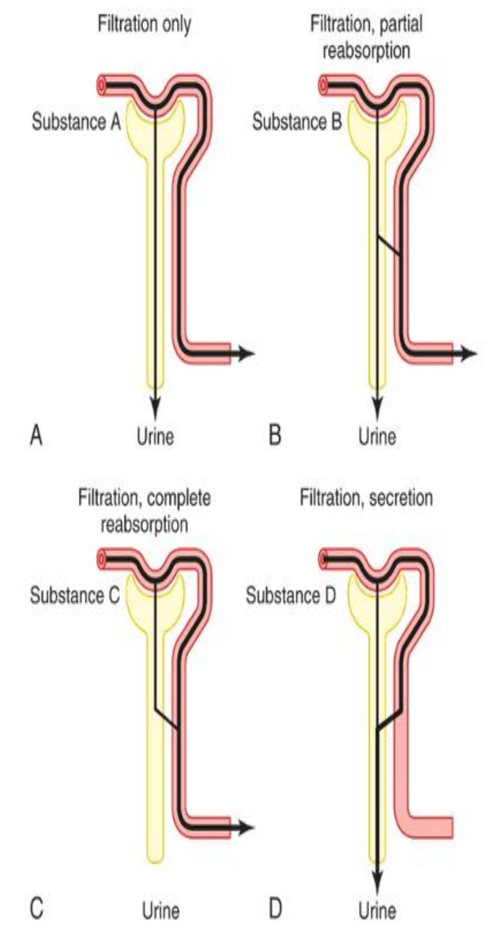
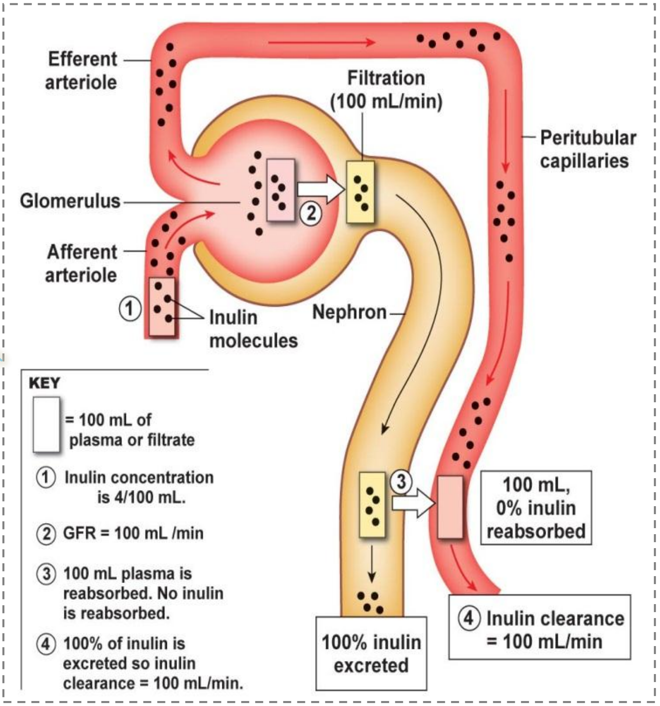


Figure 26-10

Types of clearance tests	
Endogenous	**Exogenous**
- Creatinine - Urea - Uric acid	- Inulin - Para amino hippuric acid (PAHA) - Diodrast (di-iodo pyridone acetic acid)

- **Inulin :**

A plant product that is filtered but not reabsorbed or secreted. Used to determine GFR and therefore nephron function.



Criteria of a substance used for GFR measurement

- Freely filtered
- Not secreted by the tubular cells.
- Not reabsorbed by the tubular cells.
- Should not be toxic
- Should not be metabolized
- Easily measurable.

Examples of such a substance:	
Endogenous	**Exogenous**
Creatinine by-product of skeletal muscle metabolism	**Inulin** It is a polysaccharide with a molecular weight of about 5200 and it fits all the above requirements.

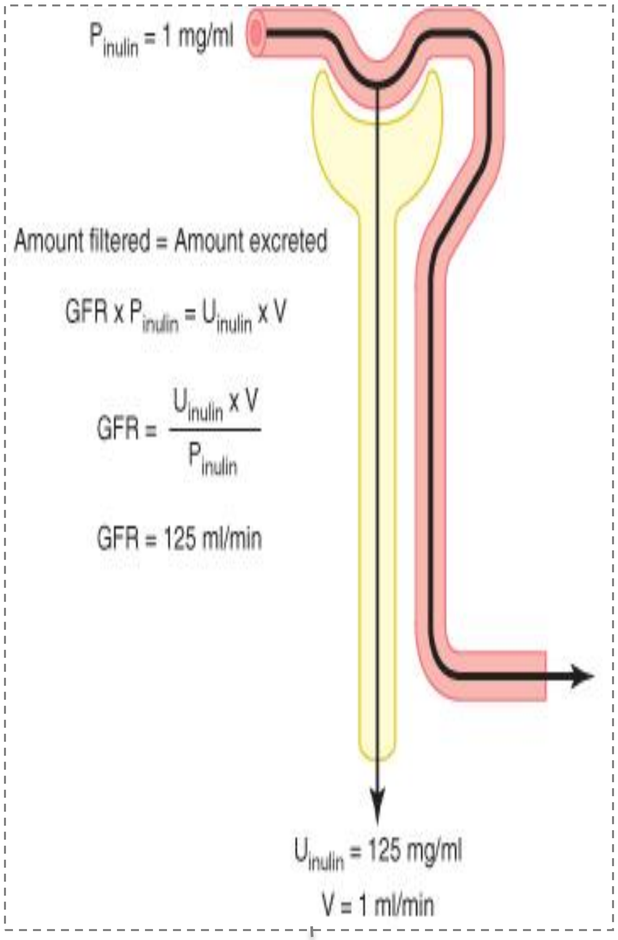
Inulin clearance : Example

if Plasma conc. of inulin = 1mg/100ml
Urinary conc. of Inulin = 120 mg /100ml
Urine flow = 1 ml /min

The clearance of inulin will be?

Clearance = **GFR** = U x V / P_X

$$= \frac{(120\ mg/100ml)(1\ ml/min)}{(1\ mg/100ml)} = 120\ ml/min$$



نفس المبدأ مع اختلاف القيم

EXTRA

- **Guyton corner :**

✓ **Inulin Clearance Can Be Used to Estimate GFR**

If a substance is *freely filtered* (filtered as freely as water) and is *not reabsorbed or secreted by the renal tubules*, then the rate at which that substance is excreted in the urine ($U_s \times V$) is *equal* to the filtration rate of the substance by the kidneys ($GFR \times P_s$). Thus,

$$GFR \times P_s = U_s \times V$$

The GFR, therefore, can be calculated as the clearance of the substance as follows:

$$GFR = \frac{U_s \times V}{P_s} = C_s$$

A substance that fits these criteria is *inulin*, a polysaccharide molecule with a molecular weight of about 5200. Inulin, which is not produced in the body, is found in the roots of certain plants and must be administered intravenously to a patient to measure GFR.

Figure 27-19 shows the renal handling of inulin. In this example, the plasma concentration is 1 mg/ml, urine concentration is 125 mg/ml, and urine flow rate is 1 ml/min. Therefore, 125 mg/min of inulin passes into the urine. Then, inulin clearance is calculated as the urine excretion rate of inulin divided by the plasma concentration, which yields a value of 125 ml/min. Thus, 125 milliliters of plasma flowing through the kidneys must be filtered to deliver the inulin that appears in the urine.
Inulin is not the only substance that can be used for determining GFR. Other substances that have been used clinically to estimate GFR include *radioactive* ***iothalamate*** and ***creatinine.***

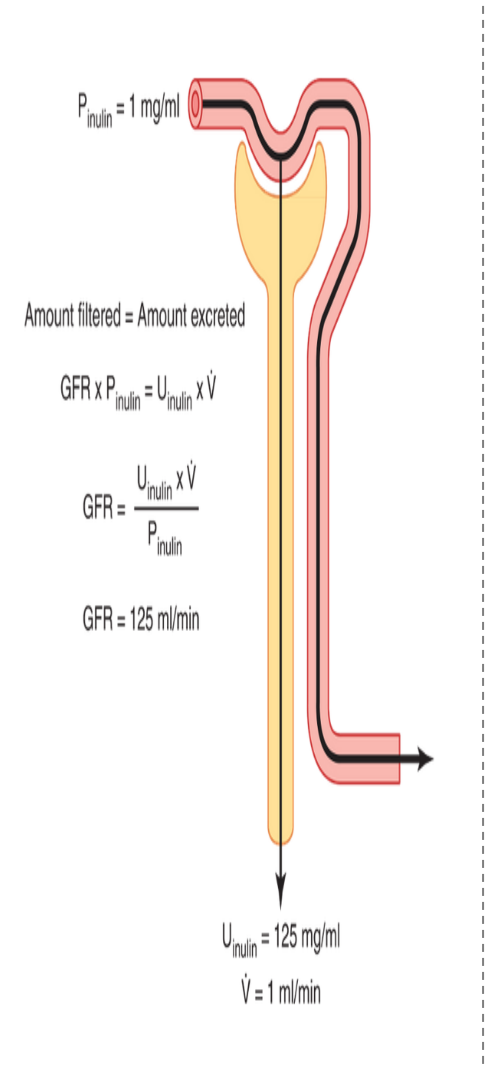


Figure 27-19

EXTRA

- **Guyton corner :**

✓ **Creatinine Clearance and Plasma Creatinine Concentration Can Be Used to Estimate <u>GFR</u>**

Creatinine is a by-product of muscle metabolism and is cleared from the body fluids almost entirely by glomerular filtration. Therefore, the clearance of creatinine can also be used to assess GFR. Because measurement of creatinine clearance does not require intravenous infusion into the patient, this method is much more widely used than inulin clearance for estimating GFR clinically. However, creatinine clearance is not a perfect marker of GFR because a small amount of it is secreted by the tubules, so the amount of creatinine excreted slightly exceeds the amount filtered. There is normally a slight error in measuring plasma creatinine that leads to an overestimate of the plasma creatinine concentration, and fortuitously, these two errors tend to cancel each other. Therefore, creatinine clearance provides a reasonable estimate of GFR.
In some cases, it may not be practical to collect urine in a patient for measuring creatinine clearance (C_{Cr}). An approximation of *changes* in GFR, however, can be obtained by simply measuring plasma creatinine concentration (P_{Cr}), which is inversely proportional to GFR:

$$GFR \approx C_{Cr} = \frac{U_{Cr} \times \dot{V}}{P_{Cr}}$$

If GFR suddenly decreases by 50%, the kidneys will transiently filter and excrete only half as much creatinine, causing accumulation of creatinine in the body fluids and raising plasma concentration. Plasma concentration of creatinine will continue to rise until the filtered load of creatinine (P_{Cr} × GFR) and creatinine excretion (U_{Cr} ×) return to normal and a balance between creatinine production and creatinine excretion is re-established. This will occur when plasma creatinine increases to approximately twice normal, as shown in Figure 27-20.
Figure 27-21 Approximate relationship between glomerular filtration rate (GFR) and plasma...
If GFR falls to one-fourth normal, plasma creatinine would increase to about four times normal and a decrease of GFR to one-eighth normal would raise plasma creatinine to eight times normal. Thus, under steady-state conditions, the creatinine excretion rate equals the rate of creatinine production, despite reductions in GFR. However, this normal rate of creatinine excretion occurs at the expense of elevated plasma creatinine concentration, as shown in Figure 27-21.

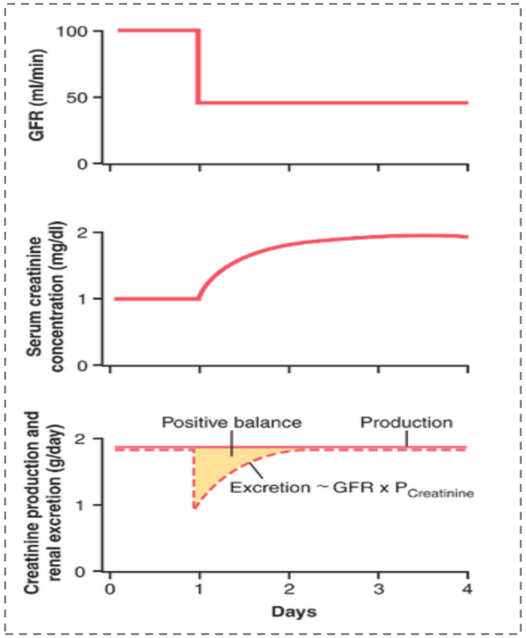


Figure 27-20

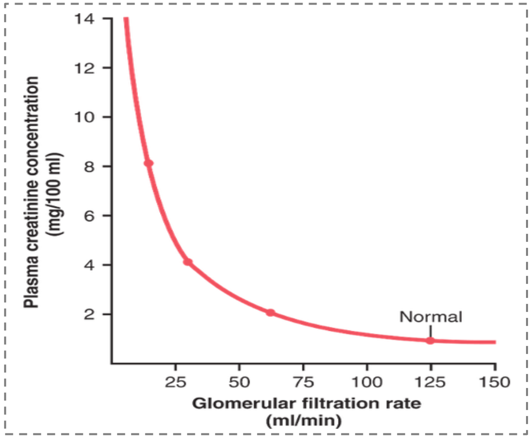


Figure 27-21

Measurement of renal blood flow

- To measure renal blood flow we will have to measure : Renal plasma flow first → then from the hematocrit we calculate the actual blood flow

Why

- Substances used for measurement of GFR are not suitable for the measurement of Renal Blood Flow

Because

- Inulin clearance only reflects the volume of plasma that is filtered and not that remains unfiltered and yet passes through the kidney → and it is known that only 1/5 of the plasma that enters the kidneys gets filtered.

Therefore

- other substances to be used with special criteria

- **Guyton corner :**

hematocrit (the percentage of red blood cells in the blood). If the hematocrit is 0.45 and the total renal plasma flow is 650 ml/min, the total blood flow through both kidneys is 650/(1 to 0.45), or 1182 ml/min.

Measurement of renal plasma flow

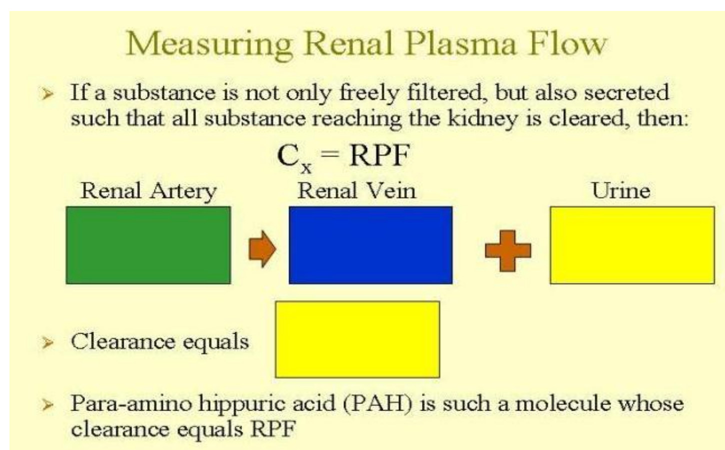
- **For the measurement of renal plasma flow, we will again need a substance that is :**

freely filtered → rapidly and completely secreted by the RTC → not reabsorbed → not toxic → easily measurable

- **Example of such substance :**

Para - Aminohippuric acid (PAH)

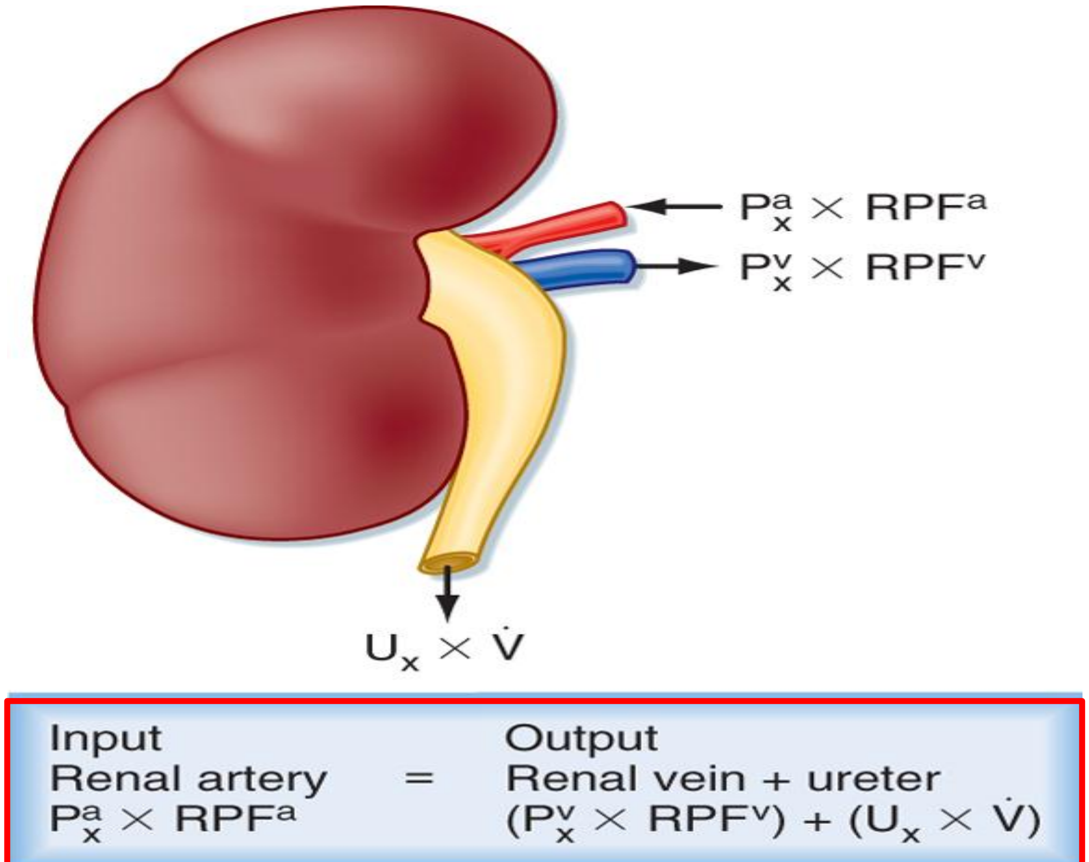
90% of plasma flowing through the kidney is completely cleared of PAH



RTC = renal tubular cell

EXTRA

- **What goes into the nephrons = What leaves the nephrons:**



P.A.H.A
(Para - Aminohippuric Acid)

- **Paraminohippuric acid (PAH)** is *freely filtered* and *secreted* and is almost *completely cleared* from the renal plasma.

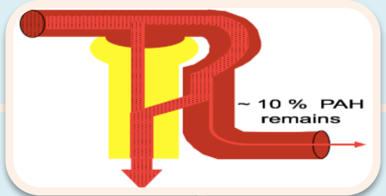
*** Uses :**

Used to measure the RBF (Renal Blood Flow)

*** Special Properties :**

When it presents below a certain conc. in the blood ;They are completely cleared from the renal plasma by a single circulation through the kidney , due to :

Easily filtered - Secreted by renal tubules - Not reabsorbed after filtration



*** Other Properties :**

- Not enter RBC's or other tissue cells.
- Not metabolized by tissues.
- Not toxic.
- Not adsorbed to the unfiltrated plasma proteins.

1. **Amount enter kidney =** RPF x PPAH
2. **Amount entered = Amount excreted**
3. **ERPF x PPAH=** UPAH x V
4. **ERPF =** $\frac{UPAH \times V}{P_{PAH}}$
5. **ERPF = Clearance of PAH**

ERPF : Effective Renal Plasma Flow

PAH clearance : Example

If the concentration of PAH in the urine and plasma and the urine flow are as follows:

- Conc. of PAH in urine=25.2 mg/ml
- Conc. of PAH in arterial blood=0.05 mg/ml

And the Urine flow =1.1 ml/min

Then CPAH or Renal Plasma Flow =

(25.2 x 1.1)/0.05 = 560 ML/ min

Lets say the hematocrit is 45%

Then renal blood flow will be:

(560 x 100)/(100-45)= 1018 ml/min

"Range = 1018-1200 ml/min"

- **Guyton corner :**

✓ PAH Clearance Can Be Used to Estimate Renal Plasma Flow

Theoretically, if a substance is *completely* cleared from the plasma, the clearance rate of that substance is equal to the total renal plasma flow. In other words, the amount of the substance delivered to the kidneys in the blood (renal plasma flow × P_s) would be equal to the amount excreted in the urine (U_s ×). Thus, renal plasma flow (RPF) could be calculated as :

$$RPF = \frac{U_s \times \dot{V}}{P_s} = C_s$$

Because the **GFR** is only about *20 percent of the total plasma flow*, a substance that is completely cleared from the plasma must be excreted by tubular secretion, as well as glomerular filtration (Figure 27-22). There is no known substance that is *completely* cleared by the kidneys. One substance, however, PAH, is about 90 percent cleared from the plasma. Therefore, the clearance of PAH can be used as an approximation of renal plasma flow. To be more accurate, one can correct for the percentage of PAH that is still in the blood when it leaves the kidneys. The percentage of PAH removed from the blood is known as the *extraction ratio of PAH* and averages about 90 percent in normal kidneys. In diseased kidneys, this extraction ratio may be reduced because of inability of damaged tubules to secrete PAH into the tubular fluid.
The calculation of RPF can be demonstrated by the following example: Assume that the plasma concentration of PAH is 0.01 mg/ml, urine concentration is 5.85 mg/ml, and urine flow rate is 1 ml/min. PAH clearance can be calculated from the rate of urinary PAH excretion (5.85 mg/ml × 1 ml/min) divided by the plasma PAH concentration (0.01 mg/ml). Thus, clearance of PAH calculates to be 585 ml/min. If the extraction ratio for PAH is 90 percent, the actual renal plasma flow can be calculated by dividing 585 ml/min by 0.9, yielding a value of 650 ml/min. Thus, total renal plasma flow can be calculated as :

$$\text{Total renal plasma flow} = \frac{\text{PAH clearance}}{\text{PAH extraction ratio}}$$

The extraction ratio (E_{PAH}) is calculated as the difference between the renal arterial PAH (P_{PAH}) and renal venous PAH (V_{PAH}) concentrations, divided by the renal arterial PAH concentration :

$$E_{PAH} = \frac{P_{PAH} - V_{PAH}}{P_{PAH}}$$

One can calculate the total blood flow through the kidneys from the total renal plasma flow and hematocrit (the percentage of red blood cells in the blood). If the hematocrit is 0.45 and the total renal plasma flow is 650 ml/min, the total blood flow through both kidneys is 650/(1 to 0.45), or 1182 ml/min.

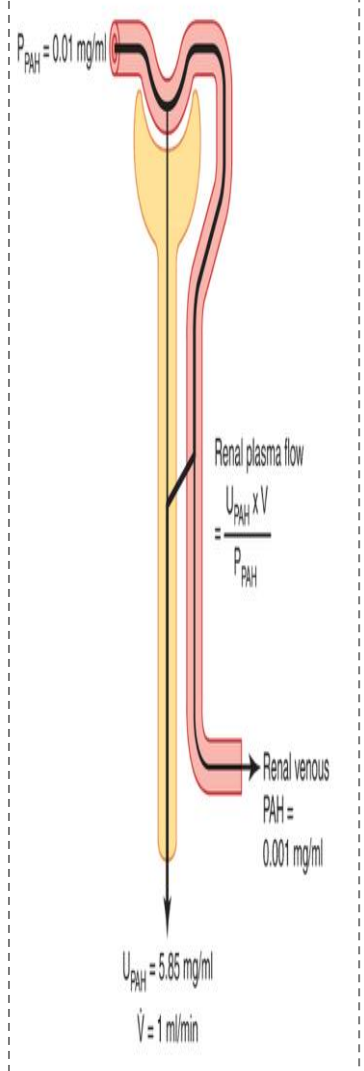
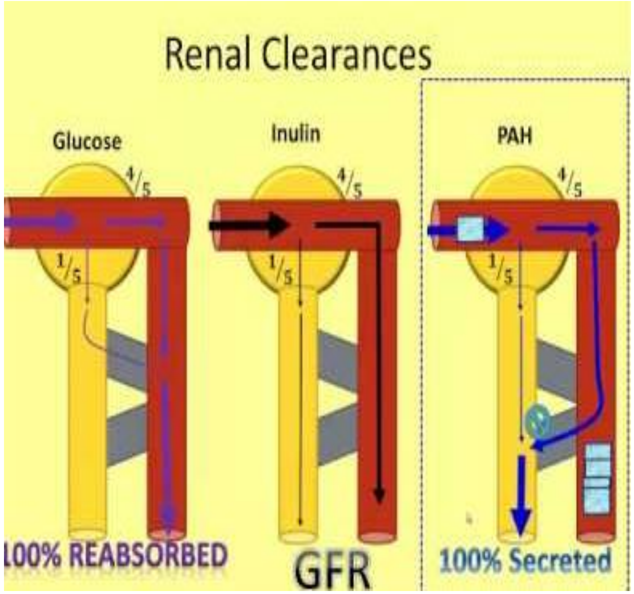


Figure 27-22

Renal clearance indications



- Renal Clearance gives an indication of the functioning of the kidneys
- Clearance can also be used to determine renal handling of a substance
- Clearance values can also be used to determine how the nephron handles a substance filtered into it

In this method the clearance for inulin or creatinine is calculated and then compared with the clearance of the substance being investigated

Comparison of clearance of a substance with clearance of inulin

Comparison of clearance of a substance with clearance of inulin		
= inulin clearance	< inulin clearance	> Inulin clearance
Only filtered not reabsorbed or secreted	Reabsorbed by nephron tubules	Secreted by nephron tubules

- **Guyton corner :**

✓ **Comparisons of Inulin Clearance with Clearances of Different Solutes**

The following generalizations can be made by comparing the clearance of a substance with the clearance of inulin, a measure of GFR:

(1) If the clearance rate of the substance *equals* that of inulin, the substance is *only filtered* and not reabsorbed or secreted

(2) if the clearance rate of a substance is *less than inulin clearance,* the substance must have been *reabsorbed* by the nephron tubules.

(3) if the clearance rate of a substance is *greater than that of inulin*, the substance must be *secreted* by the nephron tubules.

- Listed below are the approximate clearance rates for some of the substances normally handled by the kidneys:

Substance	Clearance Rate (ml/min)
Glucose	0
Sodium	0.9
Chloride	1.3
Potassium	12.0
Phosphate	25.0
Inulin	125.0
Creatinine	140.0

Calculation of tubular reabsorption or secretion from renal clearance

- Clearance measurements are also used to *examine renal management of substances absorbed or secreted by the kidney.*

For substances secreted by the kidney:
$([sub]_{plasma} \times GFR) + T = [sub]_{urine} \times V$ *(urine flow rate)*
So, What goes into the nephrons **=** What leaves the nephrons.
Secretion into nephrons is occurring when: **C sub. > C inulin**

For substances absorbed by the kidney (Nephrons):
$[sub]_{plasma} \times GFR = T + ([sub]_{urine} \times V$ *(urine flow rate)*
So, What goes into the nephrons **=** What leaves the nephrons.
Absorption from nephrons is occurring when: **C sub. < C inulin**

Conclusion	**$T = ([sub]_{plasma} \times GFR) - ([sub]_{urine} \times V)$**
Note	$[sub]_{urine} \times V$ = normally zero for glucose & amino acids.

Which means: glucose & amino acids will completely reabsorbed by the renal tubules and there will be no excretion.

T *= Amount Transported*
C sub. *= clearance of substance,*
C inulin *= clearance of inulin*

Calculation of tubular reabsorption or secretion from renal clearance

Calculation of tubular reabsorption	
Substances that are completely reabsorbed from the tubules (amino acids, glucose)	Substances highly reabsorbed (Na+)
clearance = zero because the urinary secretion is zero.	**clearance < 1%** of the GFR.

Reabsorption rate can be calculated=
Filtration rate- excretion rate
= (GFR X P*)-(U* X V)
***** *The substance needed to be assessed.*

- If excretion rate of a substance is **greater** than the filtered load, then the rate at which it appears in the urine represents **the sum of the rate of glomerular filtration + tubular secretion**

Secretion* = (U* X V)- (GFR X P*).
* indicate the substance

EXTRA

- **Guyton corner :**

✓ **Calculation of Tubular Reabsorption or Secretion from Renal Clearances**

If the rates of glomerular filtration and renal excretion of a substance are known, one can calculate whether there is a net reabsorption or a net secretion of that substance by the renal tubules. For example, if the rate of excretion of the substance (U_s ×) is less than the filtered load of the substance (GFR × P_s), then some of the substance must have been reabsorbed from the renal tubules. Conversely, if the excretion rate of the substance is greater than its filtered load, then the rate at which it appears in the urine represents the sum of the rate of glomerular filtration plus tubular secretion.

- The following example demonstrates the calculation of tubular reabsorption. Assume the following laboratory values for a patient were obtained:
  Urine flow rate = 1 ml/min
  Urine concentration of sodium (U_{Na}) = 70 mEq/L = 70 µEq/ml
  Plasma sodium concentration = 140 mEq/L = 140 µEq/ml
  GFR (inulin clearance) = 100 ml/min
  In this example, the filtered sodium load is GFR × P_{Na}, or 100ml/min × 140 µEq/ml = 14,000 µEq/min. Urinary sodium excretion (U_{Na} × urine flow rate) is 70 µEq/min. Therefore, tubular reabsorption of sodium is the difference between the filtered load and urinary excretion, or 14,000 µEq/min - 70 µEq/min = 13,930 µEq/min.

Filtration fraction

- ## Filtration fraction:

  is the ratio of GFR to renal plasma flow. *"see the equation below"*

- **Guyton corner :**

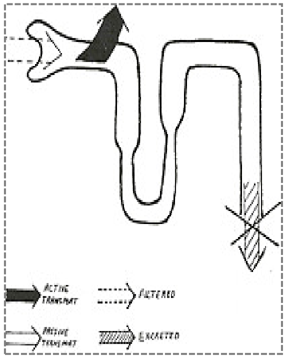
✓ **Filtration Fraction Is Calculated from GFR Divided by Renal Plasma Flow**

To calculate the filtration fraction, which is the fraction of plasma that filters through the glomerular membrane, one must first know the renal plasma flow (PAH clearance) and the GFR (inulin clearance). If renal plasma flow is 650 ml/min and GFR is 125 ml/min, the filtration fraction (FF) is calculated as :

$$FF = GFR/RPF = 125/650 = 0.19$$

Glucose clearance

- The glucose clearance is **zero** at plasma glucose values *below the threshold and gradually rises as plasma glucose rises*.



- We can express the excretion of glucose quantitatively at plasma concentrations *beyond the threshold*,

  where the glucose reabsorption rate **(T_m)** *has reached its maximum :*

Tubular transport maximum

- The Maximum limit/rate at which a solute can be transported across the tubular cells of kidneys is called **Tubular Transport Maximum**

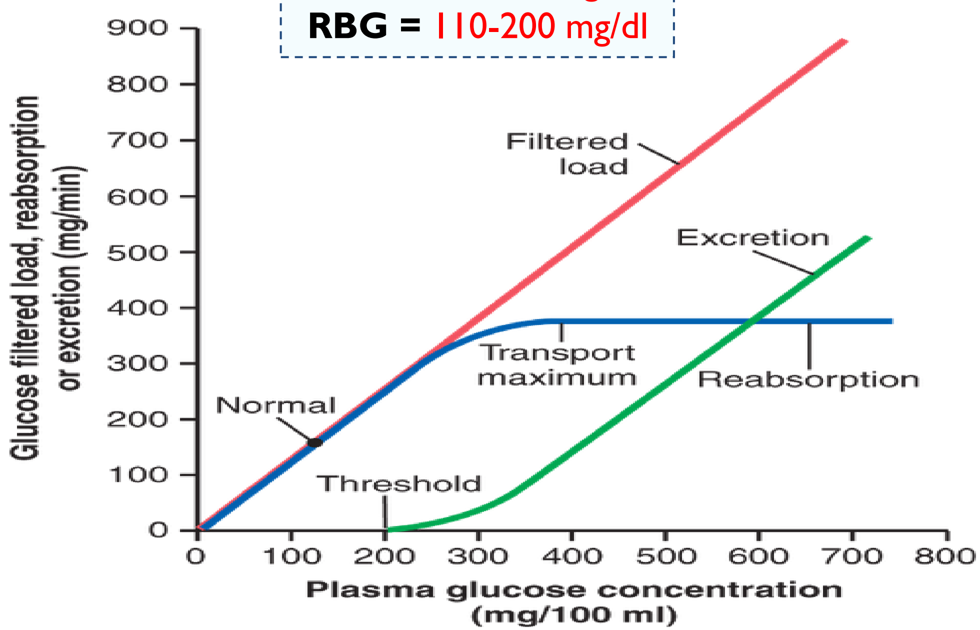
Tm for Glucose is 375 mg/min

Glucose reabsorption

Transport max : 375 mg/min

Renal Threshold : 200mg/dl

FBG = 60-110 mg/dl
RBG = 110-200 mg/dl



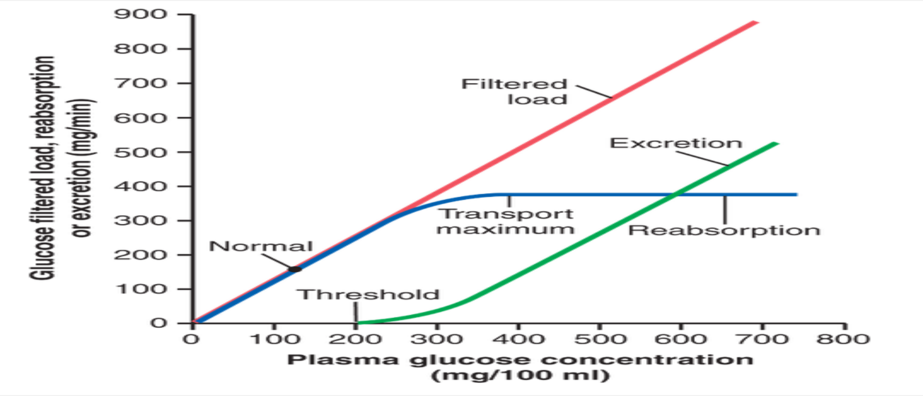
- However, when the plasma concentration of glucose rises above about 200 mg/100 ml, increasing the filtered load to about 250 mg/min, a small amount of glucose begins to appear in the urine. This point is termed the *threshold* for glucose. *Note that this appearance of glucose in the urine (at the threshold) occurs before the transport maximum is reached*. One reason for the difference between threshold and transport maximum is that not all nephrons have the same transport maximum for glucose, and some of the nephrons excrete glucose before others have reached their transport maximum. *The overall transport maximum for the kidneys, which is normally about 375 mg/min, is reached when all nephrons have reached their maximal capacity to reabsorb glucose*.

FBG : Fasting Blood Glucose / RBG : Random Blood Glucose

EXTRA

- **Guyton corner :**

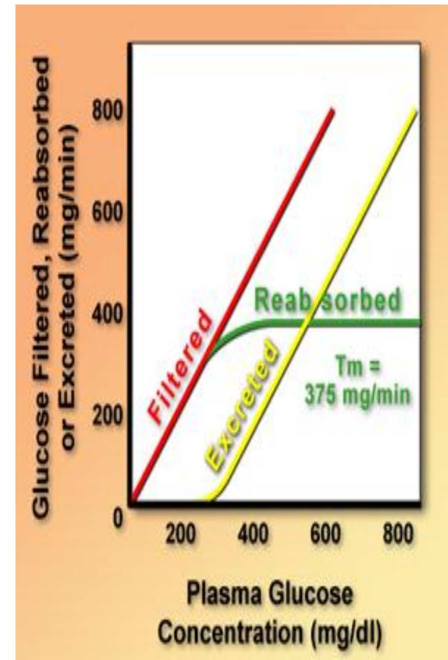
Tubular reabsorption is highly selective. Some substances, such as glucose and amino acids, are almost completely reabsorbed from the tubules, so the urinary excretion rate is essentially zero. Many of the ions in the plasma, such as sodium, chloride, and bicarbonate, are also highly reabsorbed, but their rates of reabsorption and urinary excretion are variable, depending on the needs of the body. Waste products, such as urea and creatinine, conversely, are poorly reabsorbed from the tubules and excreted in relatively large amounts.



Relations among the filtered load of glucose, the rate of glucose reabsorption by the renal tubules, and the rate of glucose excretion in the urine. The transport maximum is the maximum rate at which glucose can be reabsorbed from the tubules. The threshold for glucose refers to the filtered load of glucose at which glucose first begins to be excreted in the urine.

Tubular transport maximum for glucose

Filtered load	GFR x $[P]_{glucose}$ ↑ plasma [glucose]= ↑ Filtration
plasma [glucose] < 200	• Filtered load of glucose is *completely reabsorbed.* • clearance = zero
plasma [glucose] > 200	• Filtered load is not completely reabsorbed. • "Threshold" or plasma [glucose] at which glucose is first excreted in urine
plasma [glucose] > 350 or 375	• Filtered load is not completely reabsorbed • Na+ - glucose cotransporters are *completely saturated.* • Maximal glucose reabsorption (Tm)



Urea Clearance Test

- **Mechanism:**

Evacuates *(empty) the patient's bladder.* → Drinks a glass of water. → **After 1 hr:** *Take blood & urine samples* and drinks another glass of water. → **After 2 hrs:** Take another *urine* sample. → Calculate the urine vol. /min.

If it is above 2 ml /min
we get the maximal urea clearance (MC).
MC = 75 ml /min. (normally).

If it is below 2 ml /min
we get the standard urea clearance (SC).
SC = 54 ml /min. (normally).

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- Asrar Batarfi
- Amal alomran
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- Elham Alzahrani
- Hissah almuzini
- Johara Almalki
- Jwaher alHarbi
- Lojain alsiwat
- Munerah AlOmari
- Munira Alhussaini
- Malak alshareef
- Mai Alageel
- Nojood alhaidri
- Nora Alsomali
- Noura Alkharraz
- Noura alTawil
- Norah Alakeel
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