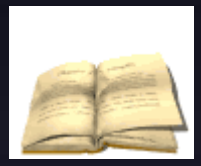
RENAL PHYSIOLOGY

PLASMA CLEARANCE



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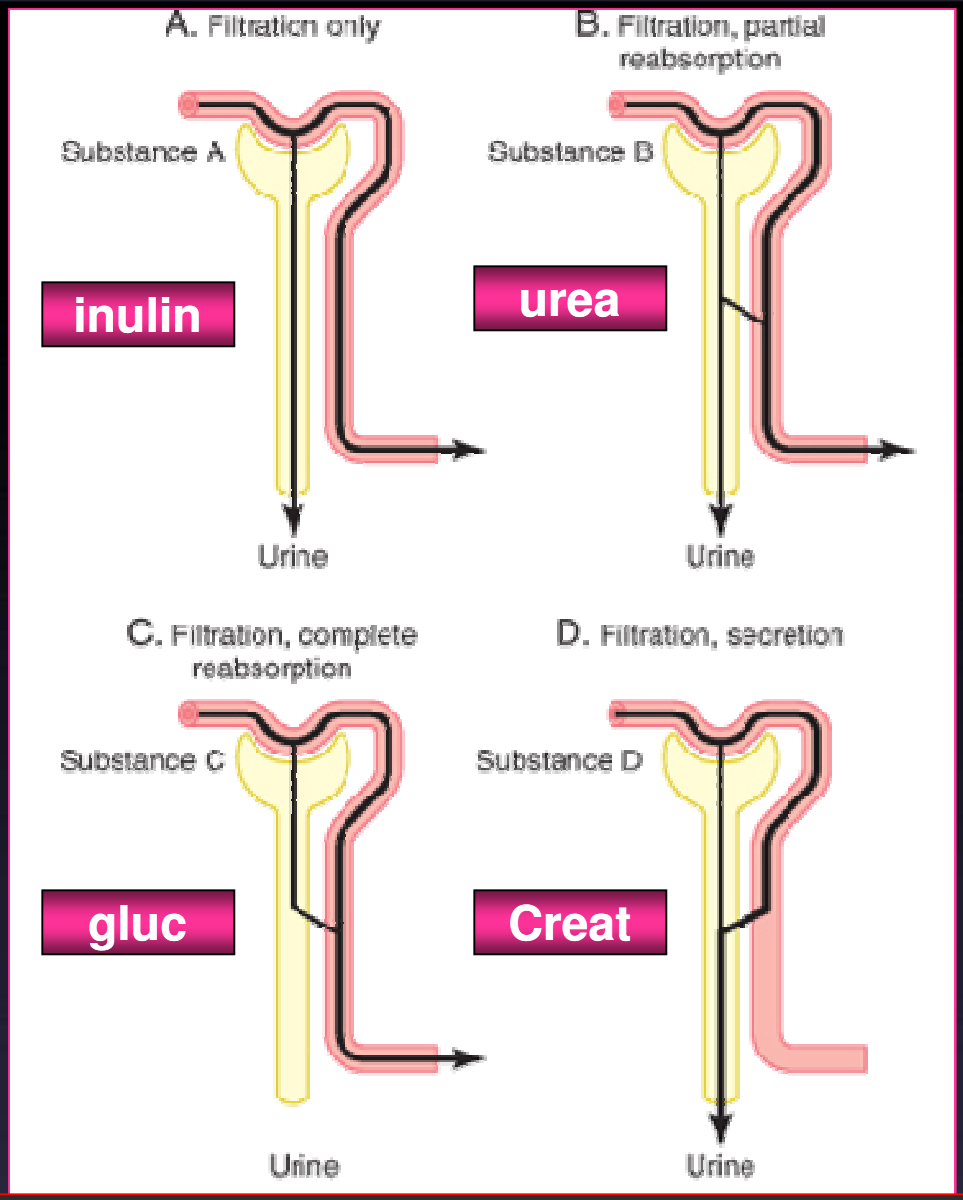
PLASMA CLEARANCE

- The Volume of Plasma that is completely cleared of any substance by the Kidneys per minute is called the clearance of that particular substance

Clearance = Urine Conc. X Vol of Urine/ Plasma Conc

FOUR POSSIBILITIES

1. Freely filtered – Not Reabsorbed – Not Secreted
2. Freely filtered – All Reabsorbed – Not Secreted
3. Freely filtered – Partially Reabsorbed – Not Secreted
4. Freely filtered – Not Reabsorbed – Secreted



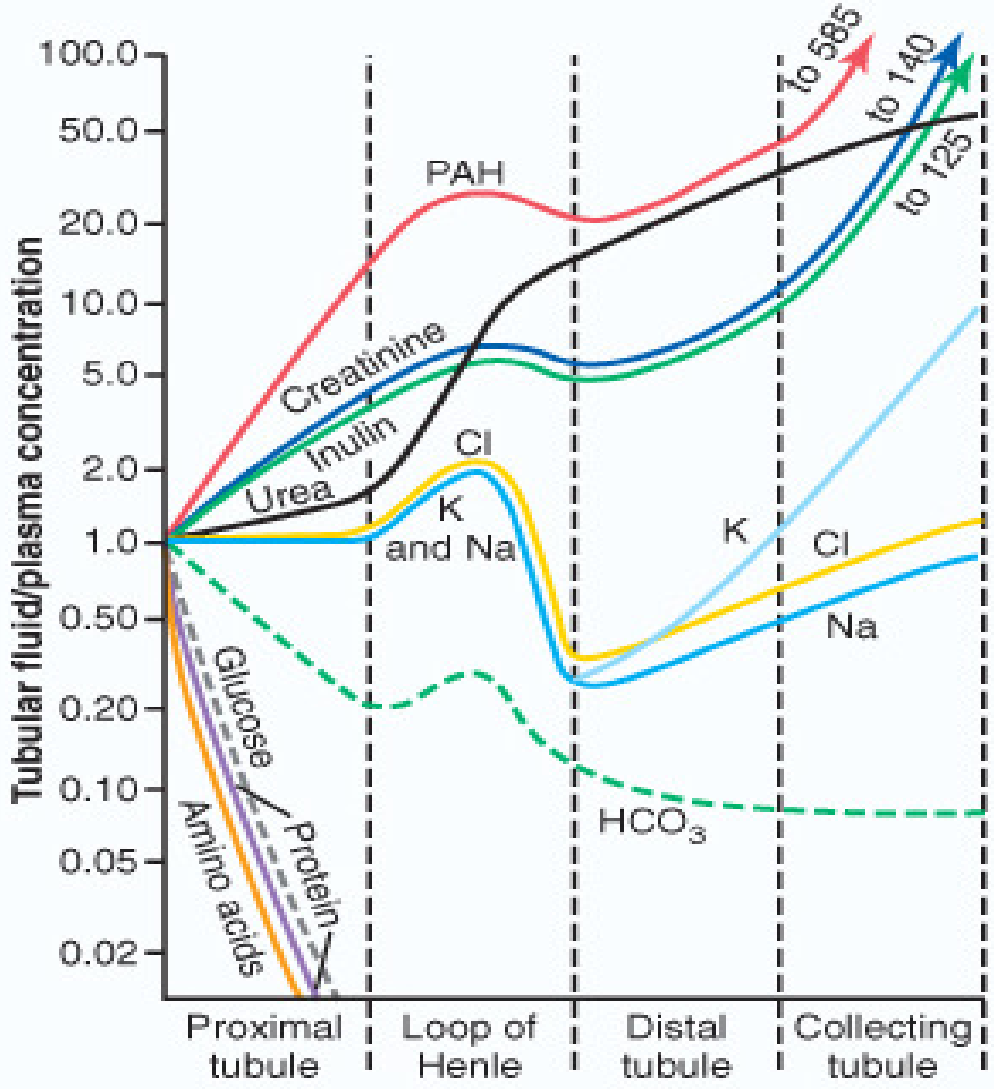
Urinary Excretion Rate = Filtration Rate – Reabsorption Rate + Secretion Rate

FILTRATE HANDLING

Relative Concentrations of Substances in the Plasma, Glomerular Filtrate, and Urine

Concentrations (mEq/1)			
Substance	***Plasma***	***Glomerular filtrate***	***Urine***
Sodium (Na^+)	142	142	128
Potassium (K^+)	5	5	60
Calcium (Ca^{+2})	4	4	5
Magnesium (Mg^{+2})	3	3	15
Chloride (Cl^-)	103	103	134
Bicarbonate (HCO_3^-)	27	27	14
Sulfate (SO_4^{-2})	1	1	33
Phosphate (PO_4^{-3})	2	2	40
Concentrations (mg/100ml)			
Substance	***Plasma***	***Glomerular filtrate***	***Urine***
Glucose	100	100	0
Urea	26	26	1820
Uric acid	4	4	53

	Amount Filtered	Amount Reabsorbed	Amount Excreted	% of Filtered Load Reabsorbed
Glucose (g/day)	180	180	0	100
Bicarbonate (mEq/day)	4,320	4,318	2	>99.9
Sodium (mEq/day)	25,560	25,410	150	99.4
Chloride (mEq/day)	19,440	19,260	180	99.1
Potassium (mEq/day)	756	664	92	87.8
Urea (g/day)	46.8	23.4	23.4	50
Creatinine (g/day)	1.8	0	1.8	0


Tubular fluid/plasma concentration
100.0
50.0
20.0
10.0
5.0
2.0
1.0
0.50
0.20
0.10
0.05
0.02
PAH
Creatinine
Inulin
Urea
Cl
K
and Na
to 585
to 140
to 125
K
Cl
Na
Glucose
Amino acids
Protein
HCO_3
Proximal tubule
Loop of Henle
Distal tubule
Collecting tubule

CLEARANCE

Vol. of Plasma to be Cleared x Plasma Conc
=
Vol. of Urine x Urine Conc (ml/min)

$$Ps \times Cs = Us \times V$$

$$Cs = Us \times V / Ps$$

- **Cs is the clearance rate of a substance s**
- **Ps is the plasma concentration of the substance**
- **Us is the urine concentration of that substance**
- **V is the urine flow rate**

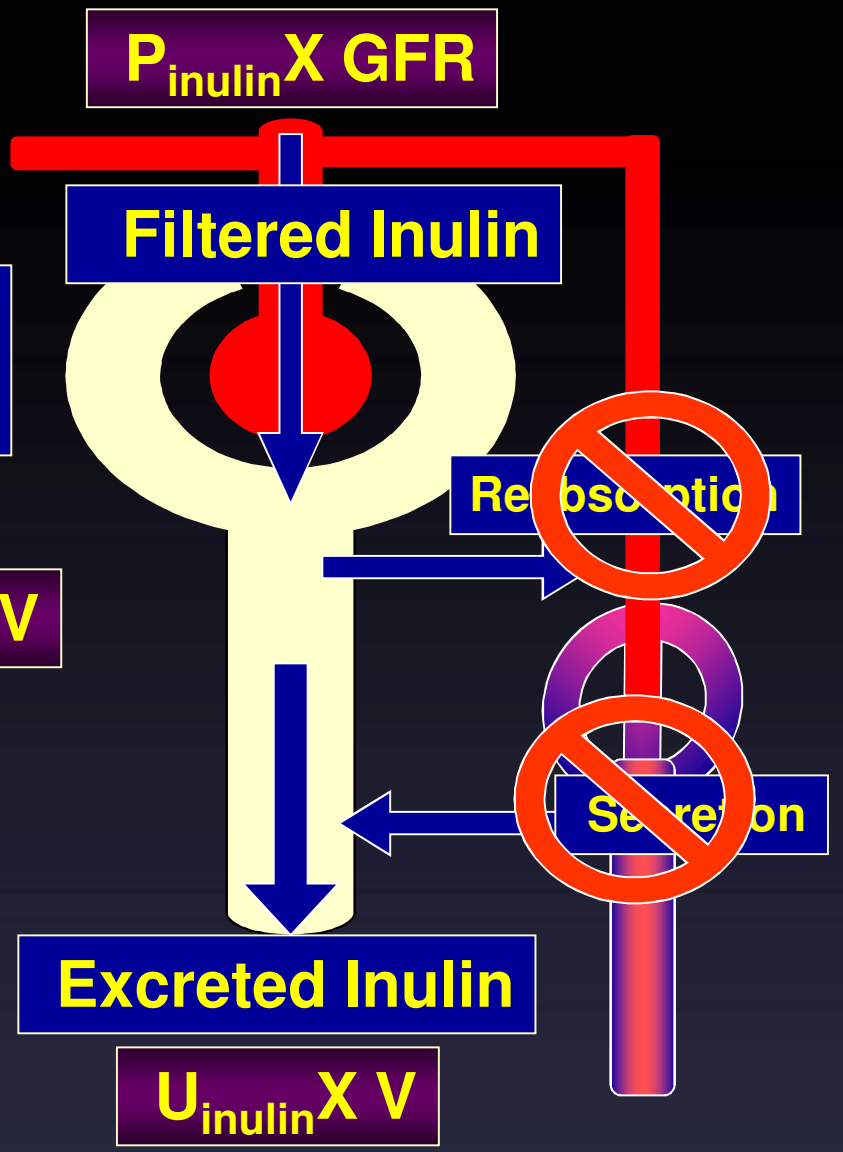
INULIN CLEARANCE

Filtered Inulin = Excreted Inulin

P_{inulin} X GFR = U_{inulin} X V

OR

$$GFR = \frac{U_{inulin} \times V}{P_{inulin}}$$



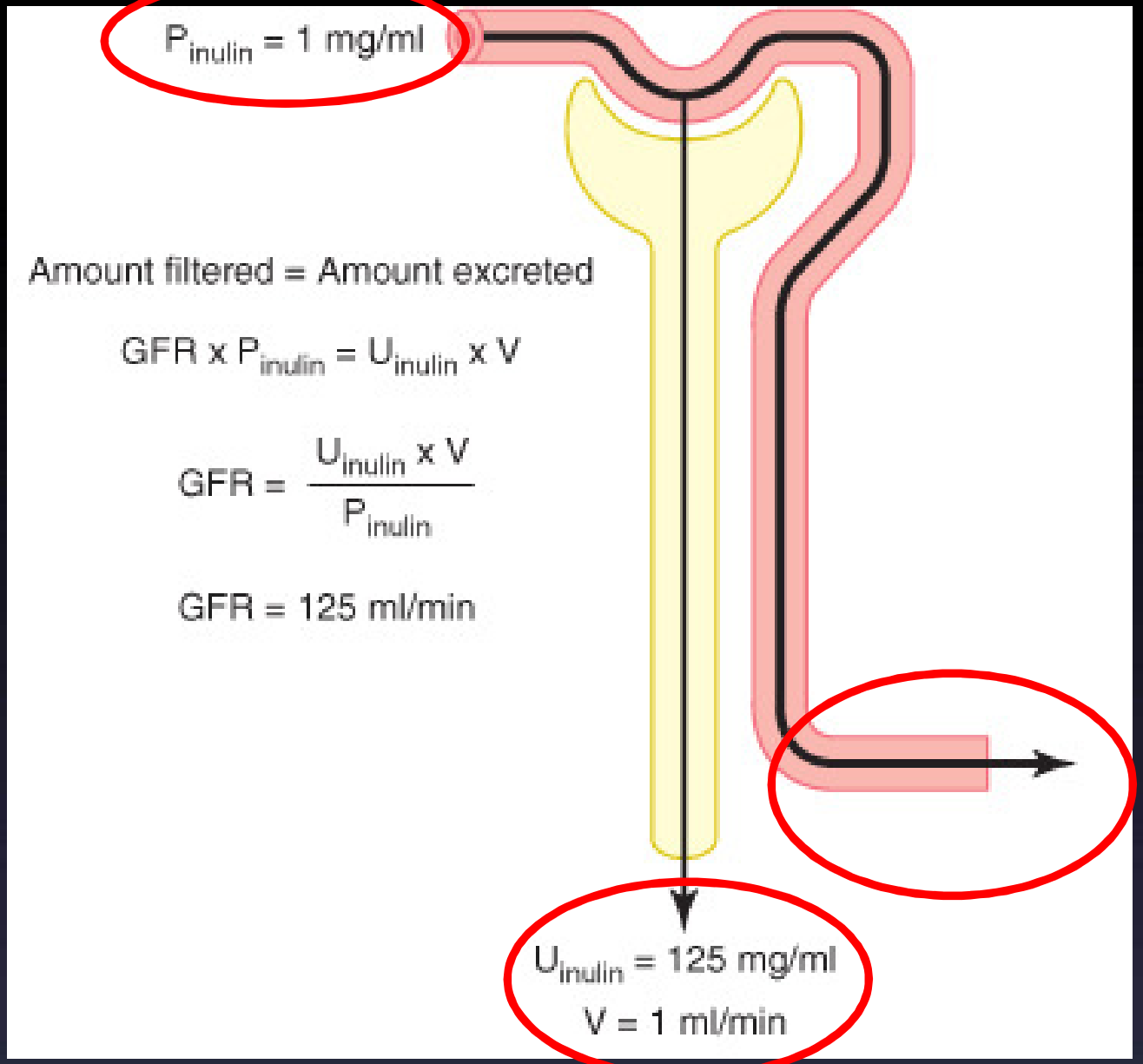
EXAMPLE

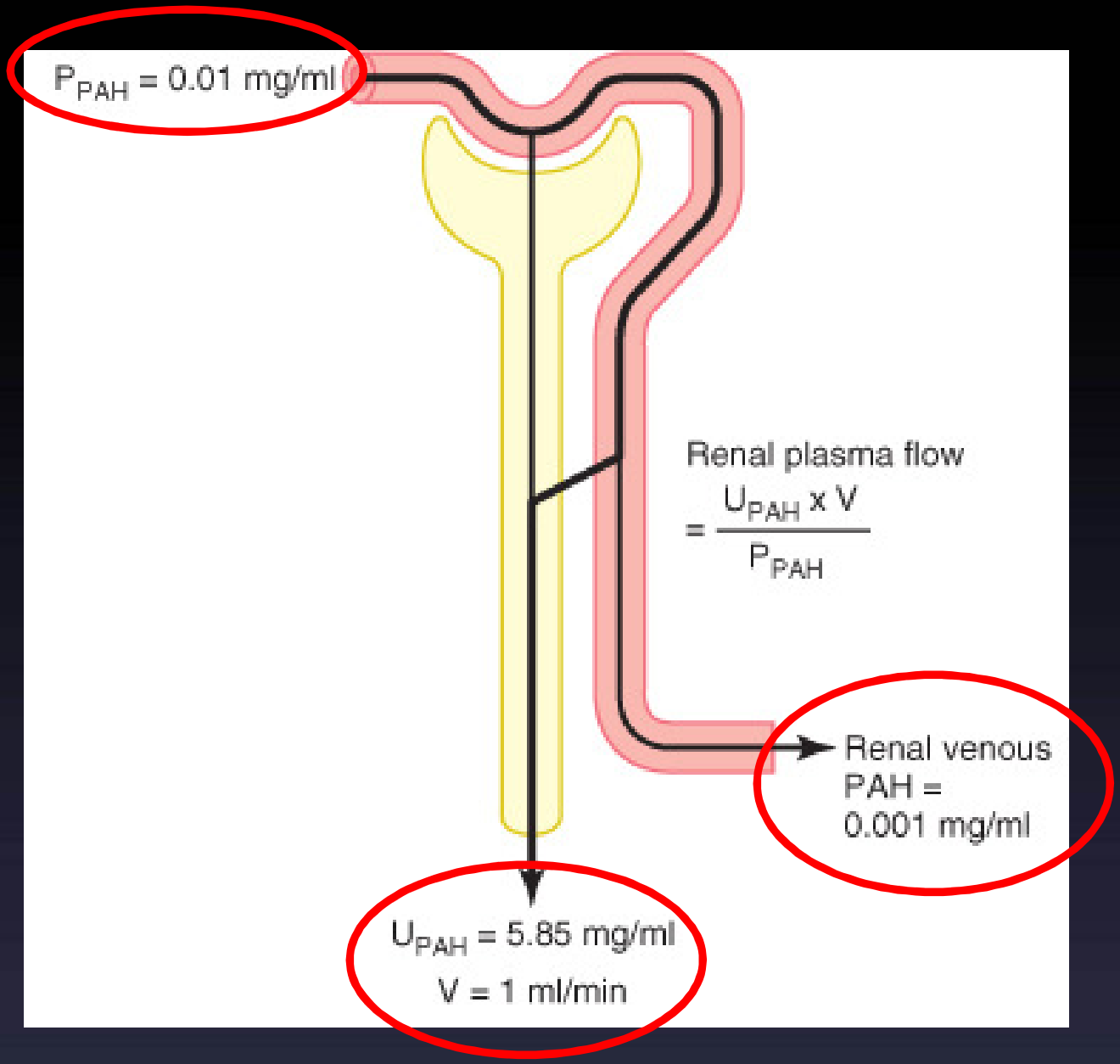
If

- Ps = 1 mg/ml
- Us = 1 mg/ml
- V = 1 ml/min

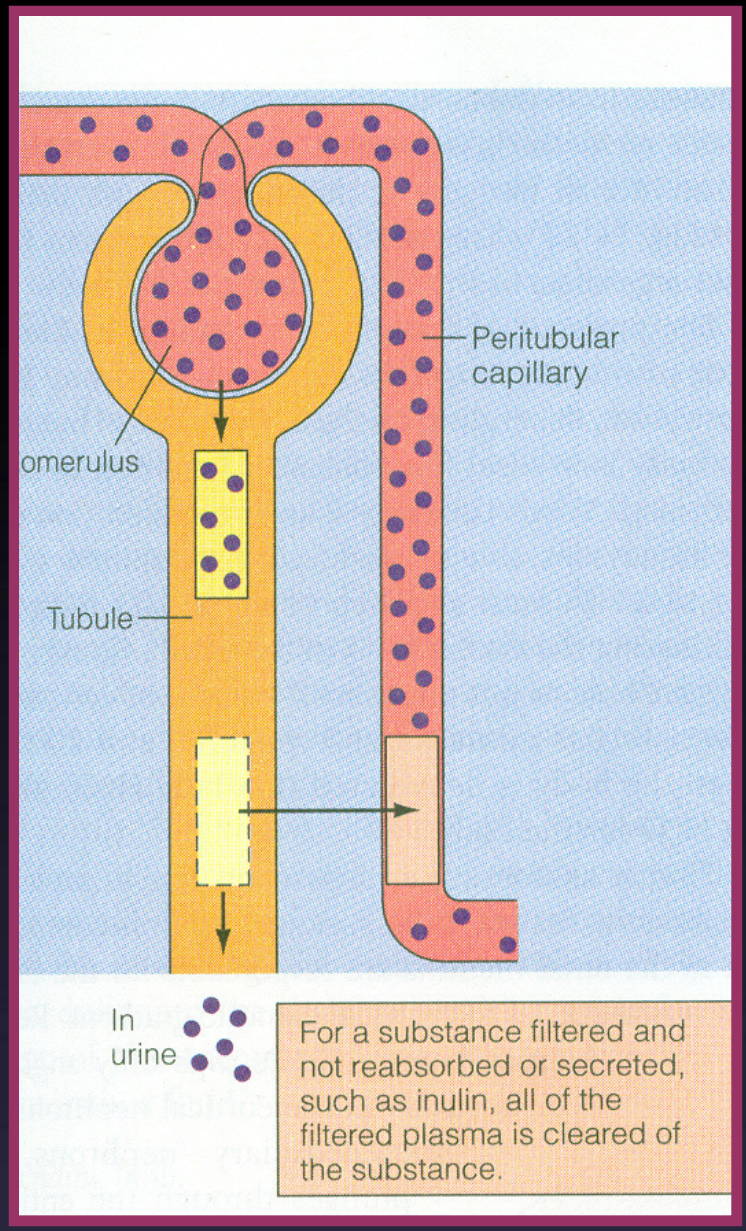
WHAT IS THE CLEARANCE OF THIS SUBSTANCE ?

CAN YOU CORRELATE IT TO GFR ?


P_{inulin} = 1 mg/ml
Amount filtered = Amount excreted
GFR x P_{inulin} = U_{inulin} x V
$GFR = \frac{U_{inulin} \times V}{P_{inulin}}$
GFR = 125 ml/min
U_{inulin} = 125 mg/ml
V = 1 ml/min


P_{PAH} = 0.01 mg/ml
Renal plasma flow
$= \frac{U_{PAH} \times V}{P_{PAH}}$
Renal venous
PAH =
0.001 mg/ml
U_{PAH} = 5.85 mg/ml
V = 1 ml/min

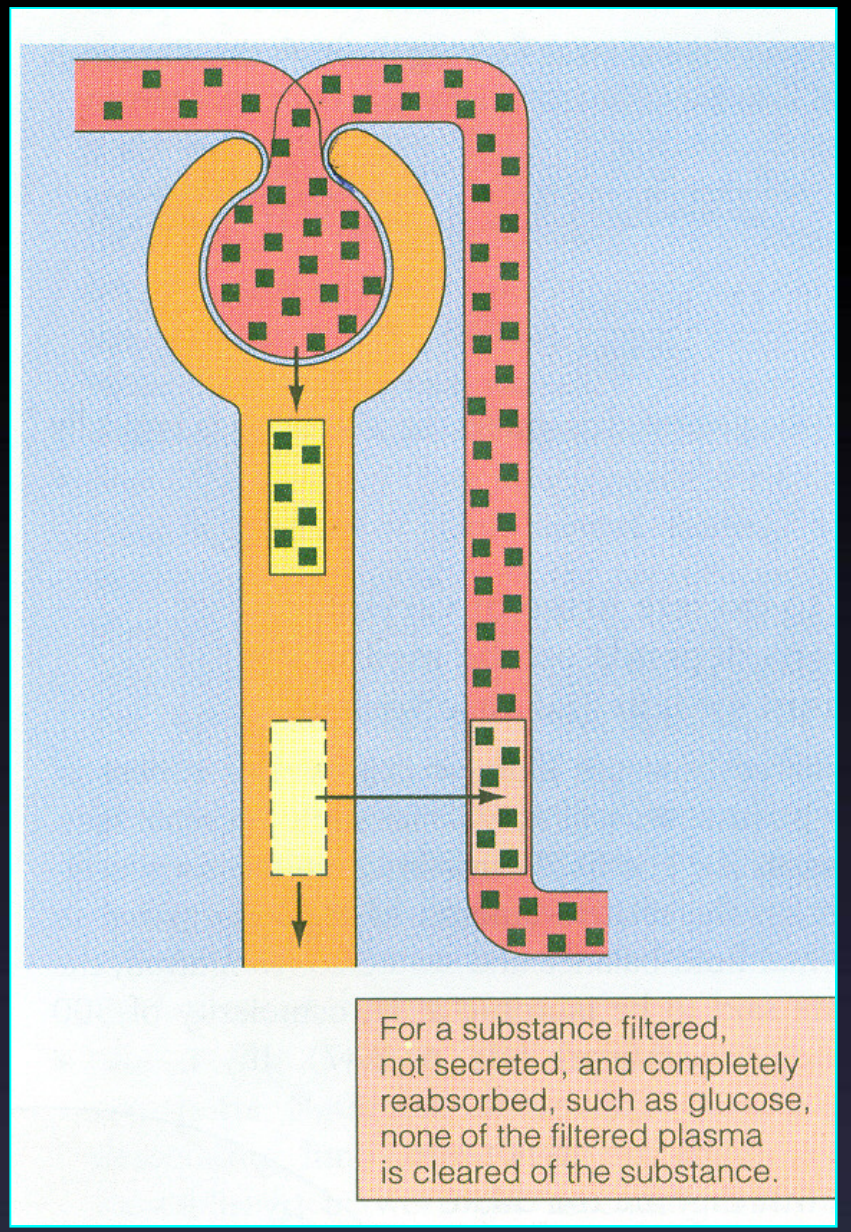
Freely filtered
Not Reabsorbed
Not Secreted



Freely filtered

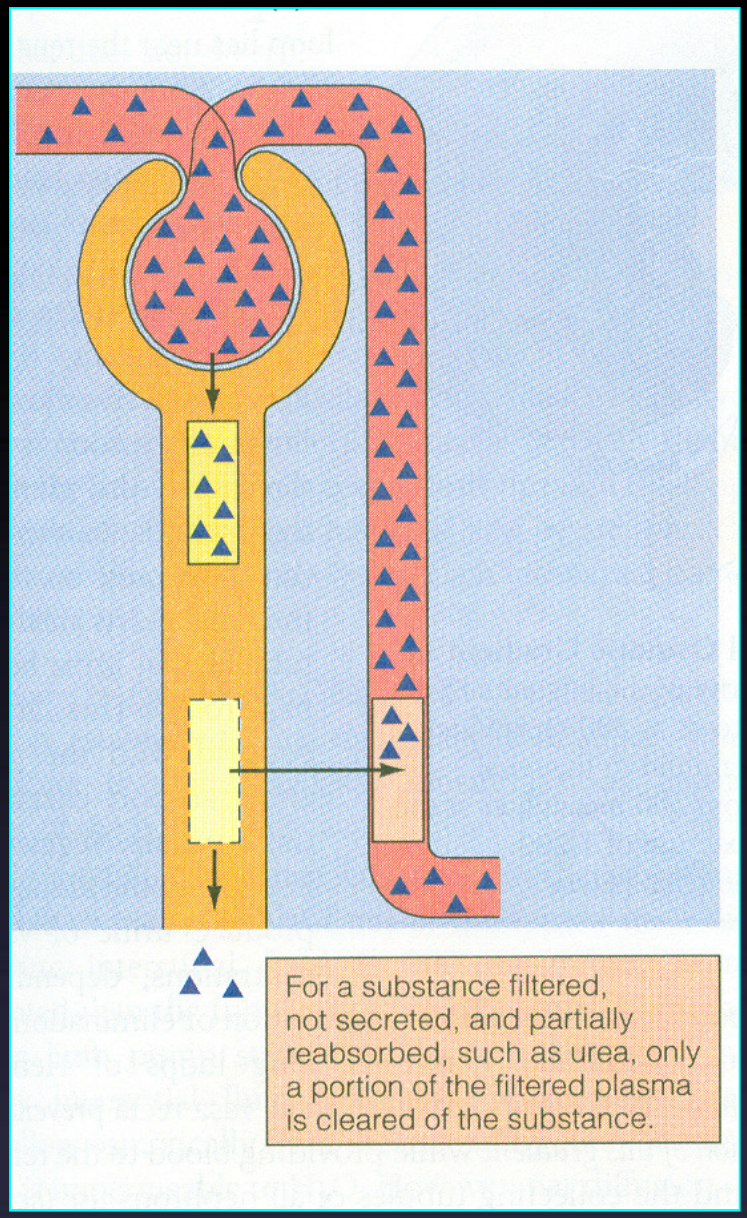
All Reabsorbed

Not Secreted

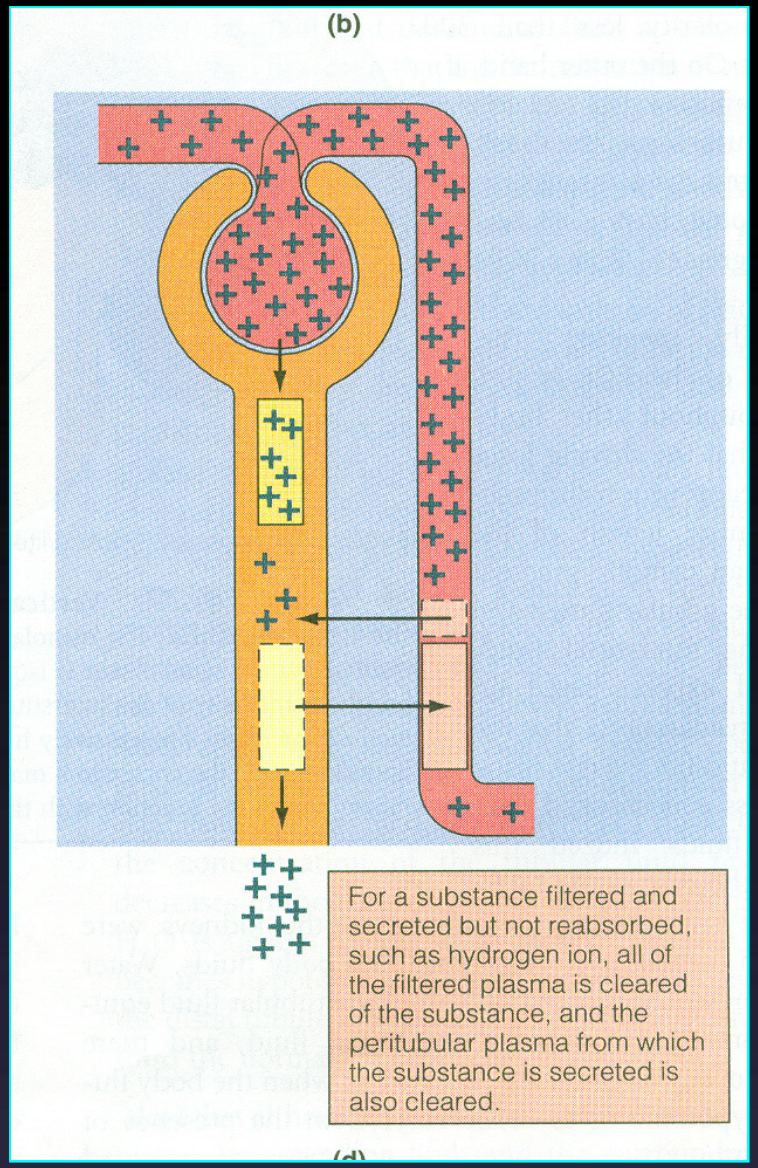


For a substance filtered, not secreted, and completely reabsorbed, such as glucose, none of the filtered plasma is cleared of the substance.

Freely filtered
Partially
Reabsorbed
Not Secreted



Freely filtered
Not Reabsorbed
Secreted

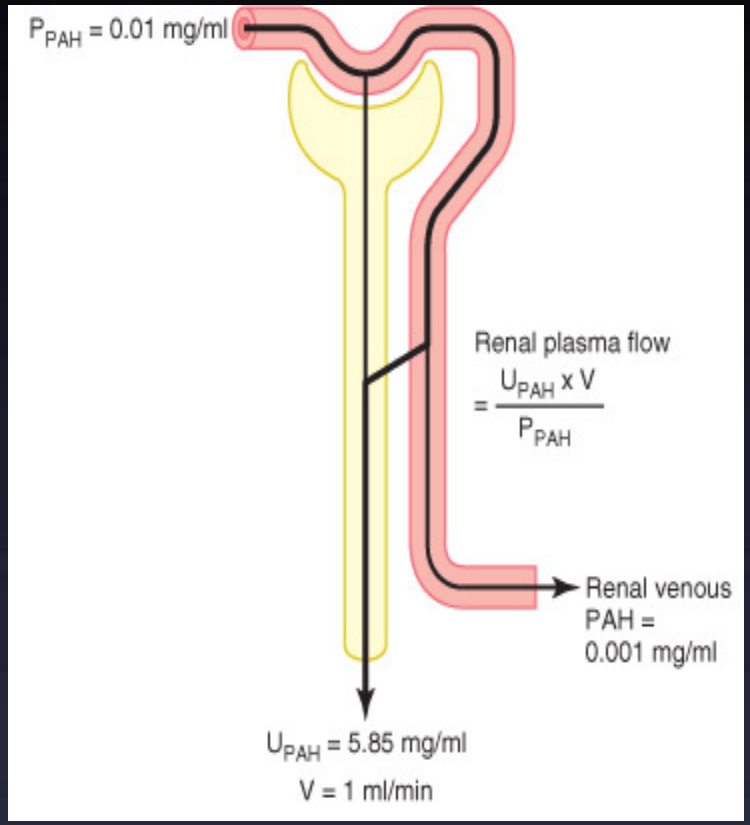


CAN YOU CORRELATE IT TO RENAL PLASMA FLOW ?

CPAH = UPAH x V/ PPAH
5.85 x 1 / 0.01 = 585
= ERPF

ARPF =
ERPF/ Extraction Ratio
= 585/0.9 = 650 ml/min

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



CAN YOU CALCULATE RENAL BLOOD FLOW NOW ?

Renal Blood Flow = RPF/ 1 - Hematocrit

650 / 1 – 0.45 = 1182 ml/min

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

RENAL FUNCTION TESTS

CREATININE CLEARANCE AS A TEST OF RENAL FUNCTION

EXAMPLE

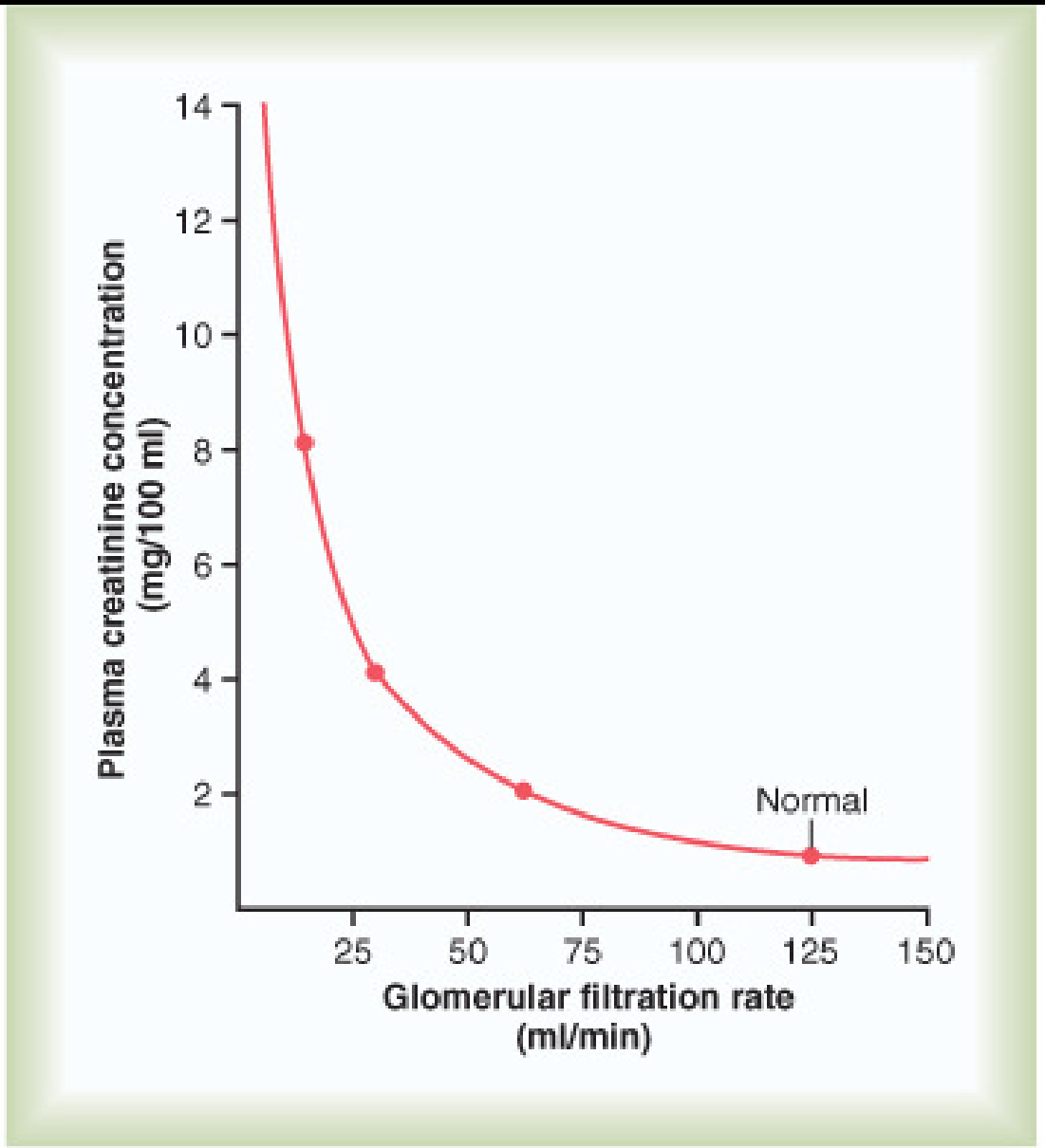
Clearance = Urine Conc. x Vol of Urine/ Plasma Conc

FOR PAH

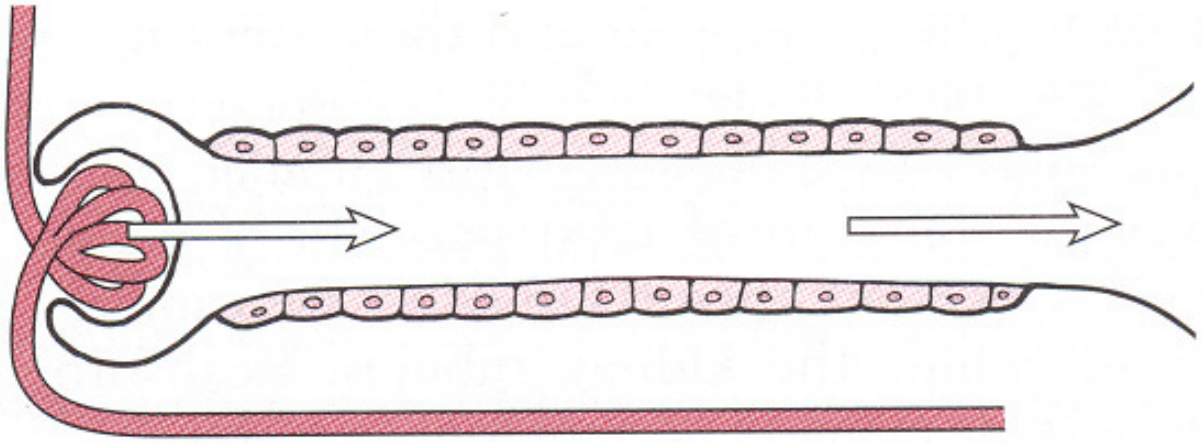
CPAH = UPAH x V/ PPAH
5.85 mg/ml x 1 ml/min/ 0.01 mg/ml = 585 ml/min
= ERPF

Actual Renal Plasma Flow = ERPF/ Extraction Ratio
= 585/0.9 = 650 ml/min

Extraction ratio (EPAH) is calculated as the difference between the renal arterial PAH (PPAH) and renal venous PAH (VPAH) concentrations, divided by the renal arterial PAH concentration



INULIN CLEARANCE EQUALS GFR



Filtered inulin
$P_{IN} \times GFR$

=

Excreted inulin
$U_{IN} \times \dot{V}$

$$GFR = \frac{U_{IN}\dot{V}}{P_{IN}} = C_{IN}$$

FIGURE 23.6 **The principle behind the measurement of glomerular filtration rate (GFR).** P_{IN} = plasma [inulin], U_{IN} = urine [inulin], $\dot{V}$ = urine flow rate, C_{IN} = inulin clearance.

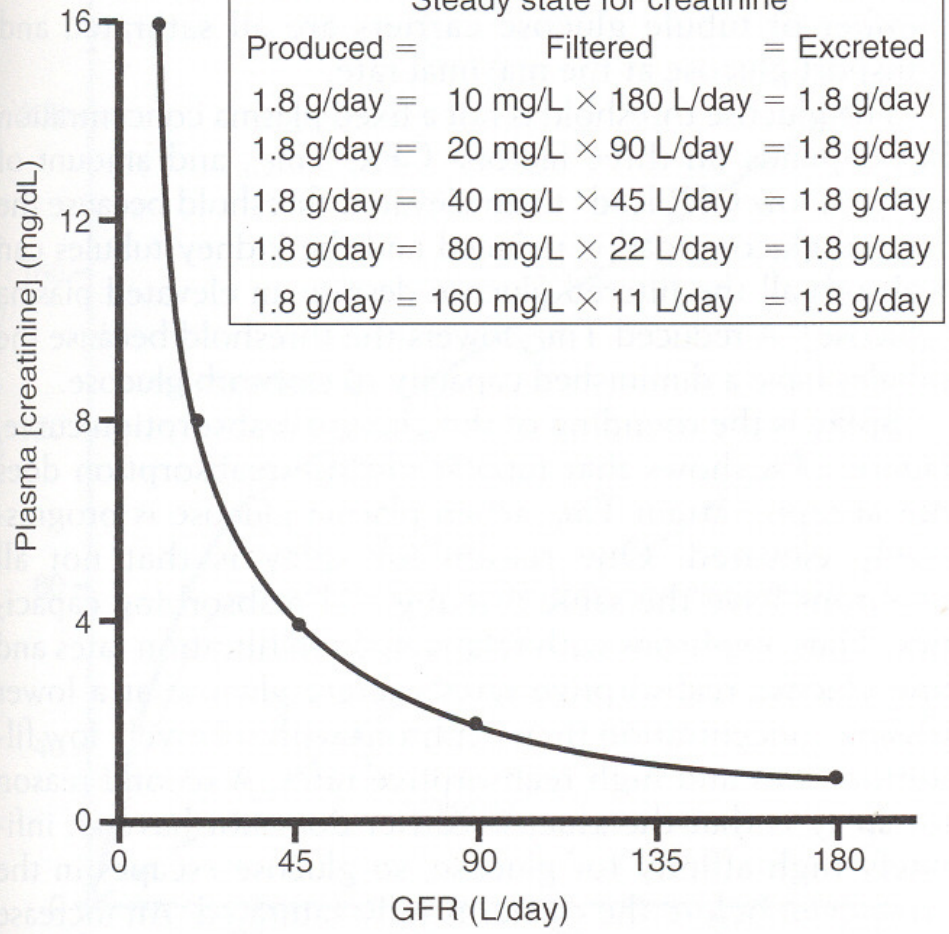


FIGURE 23.7 **The inverse relationship between plasma [creatinine] and GFR.** If GFR is decreased by half, plasma [creatinine] is doubled when the production and excretion of creatinine are in balance in a new steady state.

FILTRATE HANDLING

Relative Concentrations of Substances in the Plasma, Glomerular Filtrate, and Urine

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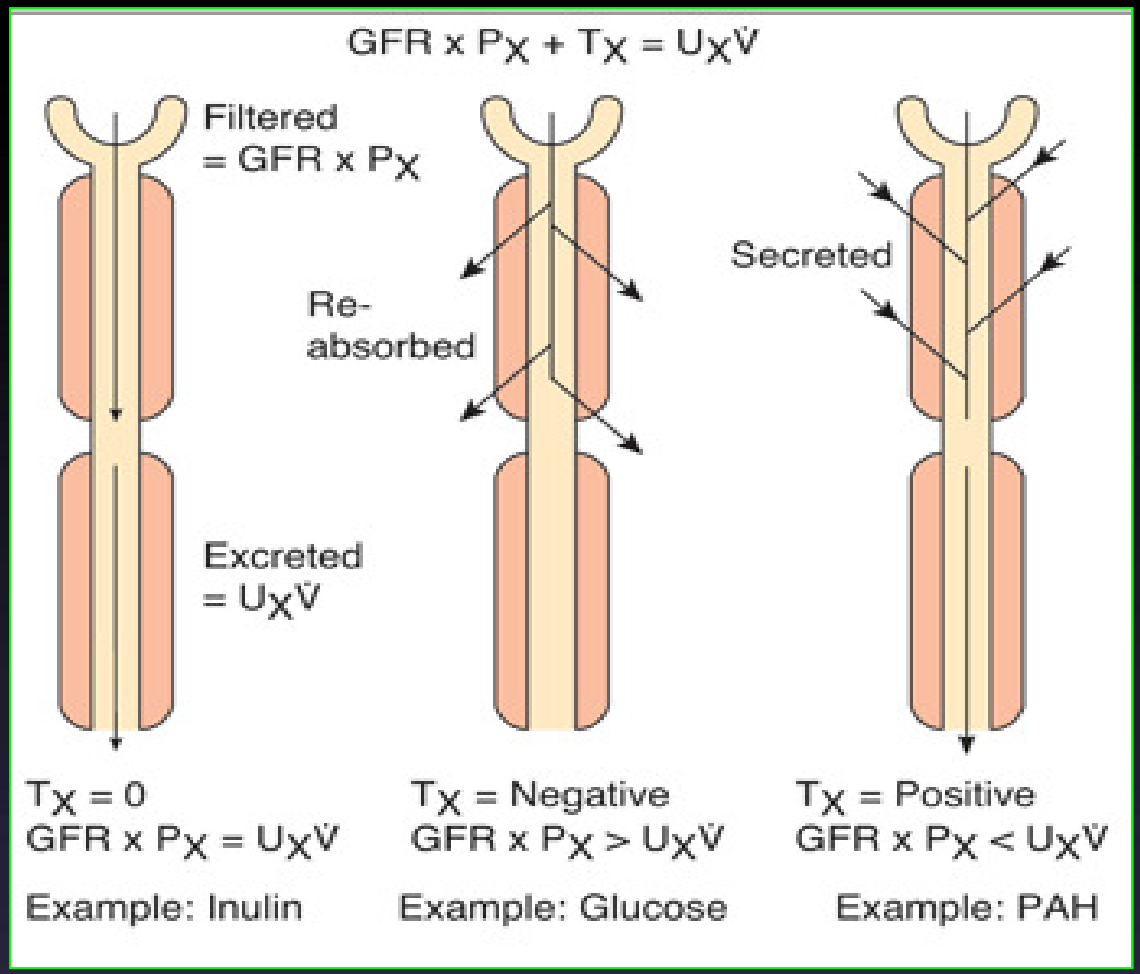
Amount Filtered = GFR X Plasma Conc

Amount Excreted / Unit Time =
Amount Filtered + Net Amount Transferred (Tx)
OR
$$U_x V = GFR \times P_x + T_x$$

UxV = GFR X Px + Tx



Tx = net amount transferred by the tubules