Bio390 **RENAL PROBLEMS**

thanks to Dr. J.F. Anderson,
Dept Zoology
Univ. of Florida, Gainesville

Calculate the rate of **pulmonary clearance** of CO_2 given the following information.

Cardiac Output: $\frac{4.8\ L}{min}$ V_E: $\frac{6\ L}{min}$

F_{ECO2}: 0.040 $[CO_2]$systemic venous blood: 54 vol%

$[CO_2]$systemic arterial blood: 49 vol%

ANS: <u>444 ml / min</u>

If we use the true definition of clearance as a virtual volume that would need to be swept clear of a substance then we would use the following equation:

C_{CO2} = rate of elimination of CO_2 / venous concentration of CO_2

> Notice that the rate of elimination of CO_2 is like the U_xV in renal clearance. Note that we use venous instead of arterial blood in this case because it is systemic venous blood (pulmonary arterial blood) that is being cleared.

= $\dot{V}_{CO_2}$ / $[CO_2]$systemic venous blood = $\dot{V}_E$ * F_{ECO2} / $[CO_2]$systemic venous blood

= (6000 mL air / min * 0.04 mL CO_2/ mL air) / 54 ml CO_2/ dl plasma

$= (240 \text{ mL } CO_2 / \text{min}) / (0.540 \text{ ml } CO_2 / \text{mL plasma})$
$= 444 \text{ ml} / \text{min}$

Notice that this is about 9.3% of the cardiac output and it gives a "filtration factor" for the lungs that is akin to that of the kidney for a freely filterable substance. But this is fortuitous -- diffusion is a very different process from hydrostatic filtration.

USE THE DATA IN THE TABLE TO ANSWER THE FOLLOWING QUESTIONS

SITE	CONCENTRATION $\frac{mg}{ml}$		
	Compound X	Glucose	Inulin
plasma	1.0	0.8	0.3
glomerular filtrate	0.6	0.8	0.3
urine	35.0	0.0	12.0

RATE OF URINE FORMATION: $\frac{3 \text{ ml}}{\text{min}}$

a. Estimate the rate of reabsorption of glucose.

ANS: 96 mg glucose/min

To answer this we need to know the filtration rate since if the clearance is zero (which for glucose it is) and if the substance is freely filterable (which glucose is), then the amount filtered equals the amount reabsorbed.

To find the amount filtered, we first need to find the GFR which in this case can be found using the inulin data (recall that the clearance of inulin normally approximates the GFR). (Note that the concentration of inulin in the filtrate is the same as in the plasma, as would be true for any freely filterable material)

$GFR = C_{inulin} = U_{inulin} * V / P_{inulin}$

= 12 mg / ml * 3 ml / min / 0.3 mg/ ml

= 120 ml/min

The amount of glucose that is filtered is the GFR times the plasma concentration of glucose:

filtered = reabsorbed = $GFR * C_{glucose}$

= 120 ml/min * 0.8 mg / ml

= 96 mg/min

b. Which of the three listed compounds probably has the largest molecular weight? What is the basis for your answer?

ANS: substance X

This is an unusual data set because we know the concentration of X in the glomerular filtrate. The filtrate concentration is below that of the plasma which means that it must NOT be freely filtered -- it is filtered alright but it has trouble getting out and so the filtering produces a concentration difference. Compare this with glucose and inulin, two substances that we know are freely filterable -- notice that as we discussed in class the filtrate concentrations of these substances equal those of the plasma.

c. Is compound X reabsorbed or secreted? Provide a quantitative answer and justification.

ANS: It is also secreted in addition to being partly filterable! This example is provided to illustrate the problems with rule making. Recall that if we assume that a substance is freely filterable, then we determine if it is also reabsorbed or secreted by calculating its clearance and then comparing it the clearance for inulin (the GFR).

So:

$C_X = U_x V / P_x$

= 35 mg/ ml * 3 ml / min / 1 mg/ ml
C_X = 105 ml/ min.

This is less than the GFR. Normally we would conclude that the substance was being reabsorbed. In fact, in this case we might be tempted to assume that the substance is being filtered only but it is so large that it is not really freely filtered. Thus, the concentration of x remains greater in the plasma than the filtrate (as we see from the filtration data) and this is supported by its clearance being lower than that of inulin.

But, we have enough data to make one other calculation. Notice that substance X is concentrated by a factor of 35 / 0.6 = 58X in going from the filtrate to the urine. By contrast, inulin, which we know is neither secreted nor reabsorbed, is concentrated by a factor of 12/ 0.3 = 40. Thus, if X were neither secreted nor reabsorbed, it should also be concentrated by a factor of 40, not 58. The short of it is that there is more X in the urine than we would expect based on the filtrate.

So the answer -- substance X is large, not very freely filtered, and then somehow some additional X is added in the PCT or perhaps DCT (unlikely). Now, this is not a real example but it shows that having too little data (clearance only) on an unknown substance can be useful but any conclusions based only on comparison of clearance with the GFR should be viewed with some caution! And speaking of caution, the final part of this analysis which dealt with concentration factors depended on the samples of urine concentration of inulin and substance X being taken at the same time. (why?)