Name Solution Student ID Number ______________________

BioE 110 Midterm # 2

1. The lab, i.e. me, wants to publish a quick paper on the effects of clove cigarettes, which have enormous amounts of tar, on alveolar ventilation rate using spirometry and CO_2 measurements. So we get Samir to smoke continuously for 24 hours and then ask him to stop coughing and breathe into a spirometer. **What do you specifically ask Samir to do to and how do you determine the following 3 lung volumes:**

   a. Tidal Volume (TD)

   Breath Normally into Spirometer. Read V_T

   b. Inspiratory Reserve Volume (IRV)

   After normal expiration, breath in as much as possible read volume

   IRV = Volume change - Tidal Volume or
   IRV = IC - TD

   c. Expiratory Reserve Volume (ERV)

   After max inhale, exhale as much as possible

   ERV = ~~TRX~~ Volume change - ~~ERV~~ IRV - V_T

   ERV = VC - IRV - TD or ERV = VC - IC

   d. When Samir is not coughing up gross stuff from his lungs, his breathing rate is 16 breaths per minute. His arterial P_{CO2} is 40 mm Hg, and the P_{CO2} of his expired air is 30 mm Hg. You measured his tidal volume as 400 ml. **What is his alveolar ventilation rate?**

$$AVR = (V_T - V_D) \cdot BR$$

need dead volume (V_D)

$$V_D = V_T \left(\frac{P_{aCO_2} - P_{ECO_2}}{P_{aCO_2}} \right)$$

$$AVR = BR \cdot V_T \left(1 - \left(\frac{P_{aCO_2} - P_{ECO_2}}{P_{aCO_2}} \right) \right)$$

$$= \frac{16}{min} \cdot 400\,ml \left(1 - \left(\frac{40 - 30\,mmHg}{40\,mmHg} \right) \right)$$

$$= \frac{16}{min} \cdot 400\,ml\,(1 - 0.25)$$

$$= \frac{16}{min} \cdot 400\,ml \left(\frac{3}{4} \right) = 48 \cdot 100\,\frac{ml}{min}$$

$$= 4{,}800\,ml/min$$

Name ________________________   Student ID Number ______________________

2. Karthik is hanging without supplemental oxygen at the summit of Mount Everest which is at an elevation of approximately 30,000 ft (8,700m). He's bored so he measures his P_{aCO2} which is 7.5 mm Hg. According to the mercury barometer in his pack, the atmospheric pressure is 247 mm Hg. Assume that the air is dry and is 80% N_2 and 20% O_2. Karthik's core temperature is 37° C, so water vapor pressure is 47 mm Hg. High altitude research has found that the *Respiratory Exchange Ratios (R)* are 0.75 and *A-a gradients* are around 5 mm Hg. **What is his Pa_{O2}** to see how he is doing oxygen-wise. **Would this be a good time to ask him for help on the next problem?**

know $P_{AO_2} - P_{aO_2} = 5$

$P_{aO_2} = P_{AO_2} - 5$ mm Hg

(need this → P_{AO_2})

Partial Pressure of O_2 in Alveolar gas

$(P_{total} - P_{H_2O})\,0.20 = P_{IO_2}$

$(247-47)(0.20) = 40$ mm Hg O_2

$P_{AO_2} = P_{IO_2} - \frac{P_{ACO_2}}{R}$ $P_{ACO_2} = P_{aCO_2}$

$= 40$ mm Hg $- \frac{P_{aCO_2}}{0.75}$

$P_{AO_2} = 40$ mm Hg $- \frac{7.5}{0.75} = 30$ mm Hg

$P_{aO_2} = P_{AO_2} - 5$

$= 30 - 5$ mm Hg O_2

$= 25$ mm Hg O_2

Normal $P_{aO_2} \sim 100$ mm Hg O_2 ⇒ Karthik's O_2 is really low. Don't ask questions.

Name ____________________ Student ID Number ____________________

3. Your colleague is assessing a patient's renal function, and doses the patient with inulin over 18 hours. During this time, the patient outputs 1.05 liters of urine. Your colleague collects a blood sample at the 12 hour time point and note the following concentrations, which this colleague asks you to analyze:

	Na^+	Creatinine	Inulin
Plasma	130 mEq/L	0.01 mg/mL	1 mg/mL
Urine	200 mEq/L	1.47 mg/mL	150 mg/mL

a. Calculate the GFR.

b. What is the clearance ratio for Na^+? How much Na^+ has been reabsorbed?

c. What is the clearance ratio for creatinine? How much creatinine has been reabsorbed?

d. Rank each ion in order of clearance (highest to lowest). Which of these ions would you use as a glomerular marker?

e. The patient filters 20% of the renal plasma flow and has a hemocrit of 0.40. Calculate the effective Renal Plasma Flow (RPF) and Renal Blood Flow (RBF).

3a GFR = clearance of inulin

$C_{inulin} = \frac{U_{inulin} \cdot \dot{V}}{P_{inulin}}$

U_{inulin} = conc. of inulin in urine

$\dot{V}$ = flow rate of inulin

P_{inulin} = conc. of inulin in plasma

$C_{inulin} = \frac{(150 \text{ mg/ml U})\left(\frac{1050 \text{ ml U}}{18 \text{ hrs}}\right)}{1 \text{ mg/ml P}}$

$\dot{V} = \frac{1050 \text{ ml}}{18 \text{ hr}} = 0.972 \text{ ml/min}$

GFR: C_{inulin} = 8.75 l/hr = 145.8 ml/min

3b. $C_{Na^+} = \frac{[U]_{Na} \cdot \dot{V}}{[P]_{Na^+}} = \frac{200 \text{ mEq/l} \cdot 0.972 \text{ ml/min}}{130 \text{ mEq/l}} = 1.495 \text{ ml/min}$

$\frac{C_{Na^+}}{C_{inulin}} = \frac{1.495}{145.8} = 0.01 \Rightarrow$ **1.03 % clearance ratio**

$\Rightarrow$ **99% of Na^+ reabsorbed**

Name ______________________ Student ID Number ______________________

3c. Creatinine

$$C_{cre} = \frac{[U]_{cre}\,\dot{V}}{[P]_{cre}} = \frac{1.47\ mg/ml \cdot 0.972\ ml/min}{0.01\ mg/ml}$$

$$= 142.9\ ml/min$$

$$\frac{C_{creat}}{C_{inulin}} = \frac{142.9}{145.8} = 0.98 = \text{clearance ratio}$$

⇒ 2% creatinine is reabsorbed.

3d ~~inulin > Na⁺ > Creatinine~~

Inulin > creatinine > Na^+

(0% 2% 99% reabsorbed)

3e Filtration fraction = FF = GFR/RPF

Effective RPF = GFR/FF

$$= \frac{145.8\ ml/min}{0.20} = \underline{729\ ml/min}$$

$$RBF = \frac{RPF}{1-H} \qquad H = \text{hematocrit}$$

$$= \frac{729}{1-0.40} = \frac{729}{0.60} = 1{,}215\ ml/min$$

Name ____________________ Student ID Number ____________________

4. The Glomerular Filtration Rate (GFR) depends on the initial filtration from leaky glomerular capillaries into the Bowman Space. The conditions in the capillary are BP = 45 mm Hg and osmotic pressure = 300 mm Hg; while in the Bowman space the pressure = 10 mm Hg and the osmotic pressure = 280 mm Hg. The hydraulic conductance (K) is 2.3 mL/(mm Hg)/hr.

   a. What components of the blood do **not** enter the Bowman Space of a healthy person?
   b. What is the flow rate into the Bowman space (i.e. the GFR)? Does your answer make sense?
   c. What happens to the GFR when the pressure in the Bowman space doubles?
   d. If the plasma protein concentration doubles, how does the GFR change?

a. RBC's & protein

b. $GPR = K\left(\left(P_{cap} - P_{BC}\right) - \left(\pi_{cap} - \pi_{BC}\right)\right)$

$= \frac{2.3\ ml}{mmHg \cdot hr}\left((45-10)\ mmHg - (300-280)\ mmHg\right)$

$= \frac{2.3\ ml}{mmHg \cdot hr}\left(35-20\right)\ mmHg$

$= (2.3)(15)\ \frac{ml}{hr}$

$= \underline{34.5\ \frac{ml}{hr} = 0.575\ ml/min}$

c. if P_{BC} doubles

$\Rightarrow \Delta P = 25\ mmHg$

$GPR = 2.3\left(5\ mmHg\right)\frac{ml}{mmHg \cdot hr}$ = GFR goes down by $\frac{1}{3}$

$= 0.19\ ml/min$

d. assume $\Delta\pi = 20$ is due to protein

$GFR = 2.3(45 - 10 - 40) = 2.3(-5)$

goes down to $-\frac{1}{3}$ the original

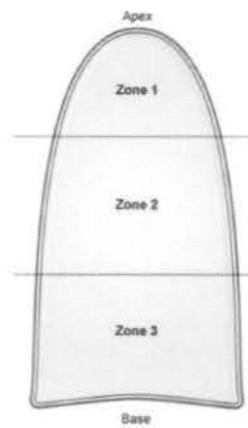
$= -0.19\ ml/min$

Name ______________________ Student ID Number ______________________

5. Because she is feeling relaxed, Tamanna goes for a walk around campus with her pet mountain lion, Fluffy. Assume that large mammals have the same lung structure and average ventilation/perfusion ratio, $\dot{V}/\dot{Q} = 0.8$, as people.

   a. **Why is the $\dot{V}/\dot{Q}$ in Zone 1 of Tamanna's lung**, which is around 3.0, **higher than the $\dot{V}/\dot{Q}$ in Zone 1 of Fluffy's lung**?

   b. During the walk, they happen to see Arnav. Fluffy decides to chase him so that they can 'play.' Arnav's stress goes up and he runs away at max speed. **How does this effect his Zone 1 $\dot{V}/\dot{Q}$ and why?**



a. Because Tamanna stands vertically, so blood vessels collapse in zone 1

$\Rightarrow$ $\dot{V}$ is ~ same, $P_{A_{O_2}} \uparrow$
$\dot{Q}$ is reduced

$\Rightarrow$ $\dot{V}/\dot{Q}$ is greater than average

Mountain lion: lung is horizontal so you don't get $\dot{Q}$ reduction

b. Arnav's $\dot{V}$ goes up, breathing harder & faster
BP $\uparrow$ so blood flows more in zone 1

$\Rightarrow$ $\dot{V}\uparrow$ $\dot{Q}\uparrow\uparrow$ $\Rightarrow$ $\frac{\dot{V}}{\dot{Q}}$ goes down & zone 1 is more effective.