PHYSIOLOGY EXAMINATION
Unit Exam #3
December 18, 1998
9:00 AM-12:00 PM

Directions: Select the one best answer and fill in the space below the corresponding letter on the answer sheet.

Respiratory Physiology Questions

(Unless otherwise noted, assume an upright, healthy lung at sea level conditions)

1. Chronic exposure to hypoxia (PIO$_2$ = 40 torr) normally leads to
   A) hypoventilation
   B) respiratory acidosis secondary to hyperventilation
   C) decreased 2,3 diphosphoglycerate in red blood cells
   D) stimulation of the central chemoreceptors
   E) a right-ward shift (increased P50) of the O$_2$-hemoglobin saturation curve

2. Overall resistance to airflow in the lung is
   A) lower during inspiration than expiration of the same tidal volume
   B) decreased by stimulation of the parasympathetic fibers that innervate the lung
   C) increased by $\beta_2$ adrenergic agonists
   D) lowest in the large airways (generation 1-5)
   E) decreased in patients during the advanced stages of cystic fibrosis

3. A decrease in lung compliance is (no change in chest wall compliance) is associated with
   A) a more negative resting intrapleural pressure (more subatmospheric)
   B) an increase in functional residual capacity (FRC)
   C) reduced muscular effort during resting inspiration to achieve normal tidal volume (500ml)
   D) A, B and C are correct
   E) A, B and C are incorrect

4. The rate of gas exchange between alveoli and capillary pulmonary blood is
   A) higher for O$_2$ than for CO$_2$ at the same partial pressure gradient between alveoli and blood
   B) perfusion-limited for carbon monoxide
   C) inversely proportional to the gas exchange surface area
   D) lower for O$_2$ at high altitude (> 15,000 ft) than at sea level
   E) is unaffected during exercise in a subject with marked global thickening of the alveolar-capillary interface

5. During moderate aerobic exercise in a healthy individual, compared to pre-exercise conditions,
   A) the arterial PO$_2$ is markedly lower than that measured during pre-exercise rest
   B) carotid chemoreceptor stimulation is responsible for the increased minute ventilation
   C) hyperventilation leads to a respiratory acidosis
   D) chemoreceptors in the lung provide the stimulus to increase alveolar ventilation
   E) minute ventilation increases in proportion to exercise intensity without a concomitant change in either arterial PO$_2$ or PCO$_2$
6. Which of the following statements is **FALSE**?

A) Surfactant reduces surface tension at the water-gas interface in the lung  
B) The fractional concentration of O₂ in the inspired air is less at high altitude than at sea level  
C) The central chemoreceptors are stimulated by increased PCO₂, but not by decreased PO₂  
D) Vital capacity can be measured by simple spirometry  
E) Velocity of airflow is inversely related to the cross-sectional area of the airways

7. During a “forced” expiration

A) the diaphragm muscle is fully contracted  
B) maximum flow is directly proportional to expiratory muscle effort  
C) intrapleural pressure often exceeds atmospheric pressure  
D) airways are stretched open  
E) alveolar pressure equals intrapleural pressure

8. Carbon dioxide

A) partial pressure is higher in the conducting airways than in the alveoli at the end of inspiration  
B) is less soluble in blood than O₂  
C) in the arterial blood is reduced during hypoventilation  
D) stimulates the central chemoreceptors, but not the carotid body chemoreceptors  
E) is transported primarily in the form of bicarbonate in the plasma

9. Which one of the following statements is **true**?

A) Stimulation of sympathetic fibers that activate the lung causes constriction of the conducting airways  
B) Impulse frequency from slowly-adapting pulmonary stretch receptors is related inversely to lung volume  
C) Residual volume can be measured by having a subject expire maximally into a spirometer  
D) The respiratory bronchioles are characterized by the presence of smooth muscle  
E) The presence of carbon monoxide in arterial blood leads to a left-ward shift (decreased P50) of the O₂-hemoglobin saturation curve

10. An alveolar-arterial gradient for O₂ (A-a O₂ gradient)

A) results from “dead space-like” conditions at the top of the lung  
B) is most often the result of an imbalance between alveolar ventilation and perfusion such that Vₐ/Q is less than unity (Vₐ/Q << 1)  
C) is the result of mild hypoventilation at sea level  
D) is reduced at altitude compared to sea level  
E) none of the above is correct

11. A patient (at sea level) with an arterial PO₂ = 100 torr, an arterial PCO₂ = 24 torr, and an R = 0.8, has an A-a O₂ gradient of

A) 5 torr  
B) 10 torr  
C) 15 torr  
D) 20 torr  
E) 25 torr

12. Which one of the following statements is **FALSE**?

A) Anemia results in a decrease in the O₂ saturation of hemoglobin at sea level  
B) Ventilation-perfusion inequality at the bottom of the upright lung leads to “shunt-like” effects  
C) An A-a O₂ gradient that results from a true anatomical shunt is not corrected by breathing 100% O₂  
D) O₂ content (ml O₂ /100 ml blood) is a better index of O₂ delivery to the tissues than is O₂ saturation of hemoglobin  
E) An increase in the P50 of the O₂-hemoglobin saturation curve facilitates the unloading of O₂ in tissues
13. Lung compliance is
   A) determined by measuring the difference between alveolar and intrapleural pressure
   B) increased in response to a global increase in airway resistance
   C) unaffected by surface tension
   D) decreased in patients with advanced emphysema
   E) increased by pulmonary surfactant

For questions 14-25 select the most appropriate response
   A) Increase(s)
   B) Decrease(s)
   C) Does not change

14. Alveolar ventilation _______________ from the top to the bottom of the upright lung.
15. Pulmonary blood flow _______________ from the top to the bottom of the upright lung.
16. The ratio of alveolar ventilation to perfusion (V_a/Q) ___________ from the top to the bottom of the upright lung.
17. Alveolar PO_2 ___________ from the top to the bottom of the upright lung.
18. Alveolar PCO_2 ___________ from the top to the bottom of the upright lung.
19. Shunt-like conditions ___________ from the top to the bottom of the upright lung.
20. Dead space-like conditions ___________ from the top to the bottom of the upright lung.
21. During a resting tidal volume, compliance __________ from the top to the bottom of the upright lung.
22. Central chemoreceptor activity ___________ in response to a drop in PaO_2 from 100 to 60 torr (CO_2 kept constant).
23. Functional residual capacity (FRC) normally ___________ in patients with increased pulmonary compliance.
24. The absence of pulmonary surfactant in the neonate ___________ lung compliance.
25. Resistance to airflow ___________ between the trachea and the respiratory bronchioles.
Renal Physiology Questions

Use the following figure to answer questions 26 to 30. Lines 1-5 illustrate how the renal clearances of five different substances change when the respective plasma concentration of each substance is increased.

![Clearance vs Plasma concentration diagram]

Match the following substances (A-E) with each curve (answers may only be used once):

A. phosphate  
B. inulin  
C. albumin  
D. sodium  
E. penicillin

26. Which substance would most closely reflect the data illustrated in line 1 of the above figure?  
27. Which substance would most closely reflect the data illustrated in line 2 of the above figure?  
28. Which substance would most closely reflect the data illustrated in line 3 of the above figure?  
29. Which substance would most closely reflect the data illustrated in line 4 of the above figure?  
30. Which substance would most closely reflect the data illustrated in line 5 of the above figure?  

Use the following data to answer questions 31 and 32.

- Amount of inulin excreted per minute ($U_{\text{inulin}}V$) = 150 mg/min  
- Urine flow rate = 1.5 ml/min  
- Concentration of inulin in arterial plasma = 1 mg/ml  
- Concentration of inulin in renal venous plasma = 0.8 mg/ml  
- Hematocrit = 50%

31. The U/P inulin ratio is:

A. 150/1  
B. 100/1  
C. 50/1  
D. 25/1  
E. cannot be calculated from the data presented.

32. Renal blood flow is (in ml/min)

A. 150  
B. 200  
C. 600  
D. 750  
E. 1500
To answer question 33, use the following data obtained from a 20-year-old man and from the same man at 80 years of age (assume all values represent steady-state conditions).

<table>
<thead>
<tr>
<th></th>
<th>20 years</th>
<th>80 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>V (liters/day)</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Plasma creatinine (mg%)</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>Creatinine production rate (g/day)</td>
<td>1.728</td>
<td>1.152</td>
</tr>
</tbody>
</table>

33. Based on these data, his
   A. GFR was higher at 80 than at 20 years of age.
   B. urine to plasma creatinine concentration ratio was higher at 20 than at 80 years of age.
   C. creatinine excretion rate was higher at 80 than at 20 years of age.
   D. his GFR at 80 was 120 ml/min.
   E. fractional volume excretion was higher at 20 compared with 80 years of age.

34. Which one of the following statements regarding the concentrations of various solutes in proximal tubular fluid (TF) and arterial plasma (P) is correct?
   A. The TF/P osmolar concentration increases from the S1 to the S2 segment.
   B. The fractional reabsorption of sodium in the S1 segment can be calculated from the TF/P chloride ratio leaving the S1 segment.
   C. The TF/P bicarbonate ratio in the S2 segment is > than 1.0 during a metabolic alkalosis.
   D. The TF/P inulin ratio can be used to calculate fractional water reabsorption.
   E. In untreated diabetes mellitus, the TF/P glucose ratio along the proximal tubule would be the same as in controls.

Use the following data sets in conditions I, II and III to answer question 35

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine osmolarity (mOs/L)</td>
<td>60</td>
<td>300</td>
<td>600</td>
</tr>
<tr>
<td>Plasma osmolarity (mOs/L)</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Free water clearance (ml/min)</td>
<td>10.0</td>
<td>0</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

35. Based on these data, which of the following statements is correct?
   A. The urine flow rate in condition I is 8 ml/min.
   B. The urine flow rate in condition III is 5 ml/min.
   C. The urine to plasma osmolar ratio is 0.5 in condition II.
   D. The osmolar clearance in condition II cannot be calculated from the data.
   E. The free water clearance in condition II is erroneous for it must be a positive value rather than zero.

36. The phenomena of pressure natriuresis and diuresis
   A. would be reduced if the renal capsule was removed.
   B. are not mediated by antidiuretic hormone (ADH).
   C. are not mediated by aldosterone.
   D. are related to increases in renal interstitial fluid pressure.
   E. all of the above are true

37. Bicarbonate reabsorption in the proximal tubule:
   A. increases when the extracellular fluid volume is expanded.
   B. increases in the presence of acetozolamide.
   C. decreases as protein intake increases (increased acid load).
   D. is a K-dependent process.
   E. results in no net acid excretion.
38. Which statement concerning the loop of Henle is correct?
   A) The water permeability of the descending limb is lower than that of the ascending limb
   B) The solute permeability of the descending limb is lower than that of the ascending limb
   C) The tubular fluid inulin concentration increases along the entire length of the ascending limb
   D) The sodium concentration in the thin ascending limb is lower than that of in the interstitium
   E) Urea entry in the thin ascending limb is offset by urea exit from the distal convoluted tubule

39. The reabsorption of sodium chloride in the thick ascending limb
   A) contributes significantly to the generation of positive free water
   B) results in water reabsorption in the thick ascending limb
   C) is co-transported with bicarbonate
   D) is stimulated by amiloride
   E) results in a tubular fluid osmolar concentration leaving the thick ascending limb which is slightly greater than arterial plasma

40. In the distal convoluted tubule
   A) the diuretic, chlorothiazide, stimulates calcium reabsorption but inhibits sodium reabsorption
   B) much of the sodium reabsorbed is via the sodium-hydrogen exchanger
   C) the sodium chloride co-transporter results in net water reabsorption in this segment of the nephron
   D) the tubular fluid inulin concentration is higher than in the thin ascending limb
   E) calcium is secreted

41. Which one of the following statements regarding potassium is correct?
   A) Hyperkalemia results in a decrease in bicarbonate reabsorption
   B) Hyperkalemia is associated with a extracellular alkalosis but an intracellular acidosis
   C) Hyperkalemia is often treated with antagonists of insulin
   D) Hypokalemia is more frequent when treating patients with loop diuretics plus amiloride than with loop diuretics alone
   E) Hypokalemia is a direct stimulus for aldosterone secretion by the adrenal cortex

42. The glomerular filtration rate (GFR) in a healthy 20 year old person
   A) will decrease if the afferent arteriole dilates.
   B) will increase if the efferent arteriole dilates.
   C) exceeds the clearance of sodium on a high sodium diet (intake = 420 mEq/day) by about 60 fold.
   D) decreases if tubular flow rate past the macula densa is reduced.
   E) decreases following the digestion and absorption of a meal with a large amount of high protein.

43. Which of the following is true regarding the renal handling of creatinine? In the steady-state
   A) amount of creatinine produced is greater than the amount of creatinine excreted
   B) amount of creatinine excreted is less than the amount of creatinine filtered
   C) amount of creatinine produced equals the amount of creatinine excreted even under conditions of decreases in the GFR
   D) plasma concentration of creatinine remains constant even under conditions of decreases in the GFR
   E) clearance of creatinine is equal to the renal plasma flow (RPF)
Use the following data to answer question #44.

- Arterial plasma concentration of X: 0.5 mg/ml
- Renal venous concentration of X: 0.05 mg/ml
- Urine flow rate (V): 1 ml/min
- Urine inulin concentration (U_{inulin}): 200 mg/ml
- Arterial plasma inulin concentration (P_{inulin}): 2 mg/ml
- Arterial plasma PAH concentration: 10 mg/ml
- Renal extraction of PAH (E_{PAH}): 1.0
- Urine PAH concentration: 5000 mg/ml

44. Based on these data, which statement relating to the renal handling of substance X is correct?

A) X is not likely to be actively transported
B) The clearance of X would not be affected by the plasma concentration of X
C) The clearance of X is the same as the clearance of inulin
D) The clearance of X is 450 ml/min
E) The clearance of X would increase as the plasma concentration of X was increased

45. Under normal conditions, which one of the following normally has the highest renal clearance?

A) Glucose
B) Amino Acids
C) Sodium
D) Potassium
E) Some low molecular weight proteins

46. In the presence of antidiuretic hormone

A) fluid entering the distal convoluted tubule is hypotonic to plasma
B) fluid leaving the cortical collecting duct (entering the outer medulla) is hypertonic to plasma
C) fluid leaving the cortical collecting duct (entering the outer medulla) is hypotonic to plasma
D) fluid leaving the proximal convoluted tubule is hypertonic to plasma
E) cyclic GMP concentrations in the cells lining the collecting duct are higher than when ADH is not present

47. Potassium secretion in the aldosterone sensitive segment of the nephron

A) is increased as the transtubular potential decreases (moves towards zero)
B) is increased during treatment with the diuretic, amiloride
C) is increased during treatment with most diuretics that inhibit sodium reabsorption in regions proximal to that site
D) is increased during treatment with inhibitors of aldosterone such as spironolactone
E) decreases as potassium intake increases

48. Free water clearance

A) is positive when the urine to plasma (U/P) osmolar ratio is greater than 1.0
B) is negative when the U/P osmolar ratio is less than 1.0
C) is zero when the U/P osmolar ratio is 2 and the urine flow rate is 2
D) will approach zero during a maximum diuresis with furosemide
E) all of the above are correct
49. During a 12-month interval, a patient's GFR has gradually decreased from 100 ml/min to 50 ml/min. Assuming no changes in her food and water intake, that no other variables had changed, and that the patient is in a new steady-state

A) her plasma glucose concentration would have increased
B) her fractional sodium excretion would have increased
C) her plasma potassium concentration would have increased
D) her plasma creatinine concentration would have increased 3-fold
E) the amount of creatinine she is excreting per minute with a GFR of 50 ml/min is less than she was excreting per minute with a GFR of 100 ml/min

50. During a metabolic acidosis

A) bicarbonate excretion increases
B) the pH in the proximal tubule would remain at about 7.0
C) a carbonic anhydrase inhibitor would correct the low plasma pH
D) the major increase in H^+ ion excretion that would occur after several days is via titratable acid
E) the base excess increases

Use the following Darrow-Yannet diagrams labeled A-F to answer questions 51-54. Answers may be used once, more than once or not at all.

Normal State

Dehydration

Overhydration

51. Which figure reflects the situation of a hemorrhage?

52. Which figure reflects the situation during the syndrome of inappropriate antidiuretic secretion (SIADH)?

53. Which figure reflects liver dysfunction?

54. Which figure reflects adrenal insufficiency?
Acid-Base Physiology Questions

55. Base excess
   A) increases during an acute respiratory alkalosis
   B) decreases during an acute respiratory acidosis
   C) increases during a metabolic alkalosis
   D) increases during a metabolic acidosis
   E) is defined as the amount of acid or base needed to titrate a blood sample to 7.4 while maintaining the PCO2 at 20 torr

Use the following figure with PCO2 isobars X, Y and Z (PCO2 = 40 mmHg), buffer lines 1 and 2, points H to O and acid-base disorder paths indicated by lines 3, 4, 5, and 6 to answer question #56-57.

56. Which one of the following statements is true?
   A) Isobar Y defines a condition in which the PCO2 is higher than 40 mmHg
   B) Point L represents a single disorder of metabolic acidosis
   C) Point N represents a multiple disorder
   D) Isobar X defines a condition in which the PCO2 is less than 40 mmHg
   E) Relative to line 1, line 2 represents a decrease in the total buffer base

57. Which one of the following of the following statements is true?
   A) Line 4 could reflect a respiratory acidosis with the appropriate renal compensation
   B) Line 3 could reflect a single disorder of metabolic acidosis
   C) Line 6 could reflect a respiratory alkalosis with the appropriate renal compensation
   D) Line 5 could reflect a single disorder of acute respiratory alkalosis
   E) Line 4 could reflect a multiple disorder of acute respiratory acidosis combined with a metabolic alkalosis
58. The following blood chemistries are associated with which disorder(s):

pH 7.09; [H+] 82 nM; PaCO₂ 34 torr; measured plasma [HCO₃⁻] 10 mM

A. No diagnosis can be made because the data are not internally consistent
B. Acute respiratory acidosis
C. Chronic respiratory acidosis
D. Metabolic acidosis
E. Mixed respiratory acidosis and metabolic acidosis

59. Your patient has a PaCO₂ of 27 torr and you believe that she has a single disorder of metabolic acidosis. Her arterial [H⁺] should be:

A. 46
B. 56
C. 66
D. 76
E. 86

60. The following blood chemistries are associated with which disorder(s):

pH 7.33; [H⁺] 46.5 nM; PaCO₂ 60 torr; measured plasma [HCO₃⁻] 31 mM

A. No diagnosis can be made because the data are not internally consistent
B. Metabolic acidosis
C. Chronic respiratory acidosis
D. Acute respiratory acidosis
E. Mixed respiratory acidosis and metabolic acidosis

61. The following blood chemistries are associated with which disorder(s):

pH 7.60; [H⁺] 25 nM; PaCO₂ 38 torr; measured plasma [HCO₃⁻] 36 mM

A. No diagnosis can be made because the data are not internally consistent
B. Acute respiratory alkalosis
C. Chronic respiratory alkalosis
D. Metabolic alkalosis
E. Mixed metabolic alkalosis and respiratory alkalosis

Answers exam a
1e 2a 3a 4d 5e 6b 7c 8e 9e 10b 11d 12a 13e 14a 15a 16b 17b 18a 19a 20b 21a 22c 23a 24b 25b 26e 27a 28d 29c 30b 31b 32e 33e 34d 35d 36e 37e 38b 39a 40a 41a 42c 43c 44d 45d 46a 47c 48d 49b 50b 51a 52f 53d 54c 55e 56d 57b 58e 59a 60c 61e