MULTIPLE CHOICE

1. What is the primary function of the lungs?
   a. convert angiotensin I to angiotensin II
   b. filter pulmonary blood
   c. gas exchange
   d. remove carbon monoxide (CO)

ANS: C

The primary functions of the lungs are to supply the body with oxygen (O₂) and to remove carbon dioxide (CO₂).

DIF: Application   REF: p. 223   OBJ: 1
2. During each cycle of normal resting ventilation, a volume of gas is moved into and out of the respiratory tract. This cyclical volume is called the:

a. inspiratory reserve volume (IRV)
b. vital capacity (VC)
c. residual volume (RV)
d. tidal volume ($V_T$)

ANS: D

During each cycle, a volume of gas moves in and out of the respiratory tract. This volume, measured during either inspiration or expiration, is called the tidal volume, or $V_T$.

DIF: Application   REF: p. 224   OBJ: 1

3. Which of the following pressures vary throughout the normal breathing cycle?

4. alveolar pressure ($P_{alv}$)
5. body surface pressure ($P_{bs}$)
6. mouth pressure ($P_{ao}$)
7. pleural pressure ($P_{pl}$)

a. 1, 2, 3, and 4
b. 2, 3, and 4
c. 2 and 4
d. 1 and 4
Alveolar pressure ($P_{alv}$), often referred to as intrapulmonary pressure, varies during the breathing cycle. $P_{pl}$ also varies during the breathing cycle.

4. Which of the following pressures normally remains negative (relative to atmospheric pressure) during quiet breathing?

a. $P_{alv}$  
b. $P_{pl}$  
c. $P_{ao}$  
d. $P_{bs}$

ANS: B

Pleural pressure ($P_{pl}$) is usually negative (i.e., subatmospheric) during quiet breathing.

5. Which of the following pressure gradients is responsible for the actual flow of gas into and out of the lungs during breathing?

a. transcanadian pressure gradient ($P_{pc} - P_{ks}$)  
b. transpulmonary pressure gradient ($P_{alv} - P_{pl}$)
c. transrespiratory pressure gradient ($P_{alv} - P_{ao}$)
d. transthoracic pressure gradient ($P_{pl} - P_{bs}$)

ANS: C

The transrespiratory pressure gradient causes gas to flow into and out of the alveoli during breathing.

DIF: Application  REF: p. 225  OBJ: 2

6. Which of the following pressure gradients is responsible for maintaining alveolar inflation?

a. transpulmonary pressure gradient ($P_{alv} - P_{pl}$)
b. transthoracic pressure gradient ($P_{pl} - P_{bs}$)
c. transcanadian pressure gradient ($P_{ca} - P_{ks}$)
d. transrespiratory pressure gradient ($P_{alv} - P_{ao}$)

ANS: A

Transpulmonary or $P_L$ is the pressure difference that maintains alveolar inflation.

DIF: Application  REF: p. 225  OBJ: 2
7. Which of the following statements about alveolar pressure ($P_{alv}$) during normal quiet breathing is true?

a. It is positive during inspiration and negative during expiration.
b. It is the same as intrapleural pressure ($P_{pl}$).
c. It is negative during inspiration and positive during expiration.
d. It always remains less than atmospheric pressure.

ANS: C

During inspiration the pleural pressure drops, the transpulmonary pressure gradient widens, causing the alveoli pressure to become subatmospheric and gas to enter the lung. During expiration the passive recoil of the lungs cause a supra-atmospheric pressure in the alveoli that causes gas to exit the lung.

DIF: Application  REF:  p. 225  OBJ:  2

8. What happens during normal inspiration?
9. The $P_{pl}$ decreases further below atmospheric.
10. The transpulmonary pressure gradient widens.
11. $P_{alv}$ drops below that at the airway opening.

a. 1, 2, and 3
b. 2 and 3
c. 1 only
d. 1 and 3

ANS: A
As the alveoli expand, their pressures fall below the pressure at the airway opening. This “negative” (i.e., subatmospheric) transrespiratory pressure gradient causes air to flow from the airway opening to the alveoli, increasing their volume.

DIF: Application  REF:  p. 226  OBJ:  2

9. During normal tidal ventilation, the transpulmonary pressure gradient ($P_{alv} - P_{pl}$) reaches its maximum value at what point in the cycle?

a. mid-inspiration
b. end-expiration
c. end-inspiration
d. mid-expiration

ANS: C

At this point, called end-inspiration, alveolar pressure has returned to 0 and the transpulmonary pressure gradient reaches its maximal value (for a normal breath) of approximately $-10$ cm H$_2$O.

DIF: Application  REF:  p. 225  OBJ:  3

10. During expiration, why does gas flow out from the lungs to the atmosphere?

a. $P_{alv}$ is less than at the airway opening.
b. $P_{alv}$ is the same as at the airway opening.
c. $P_{alv}$ is greater than at the airway opening.
d. Airway pressure is greater than $P_{alv}$.
ANS: C

As expiration begins, the thorax recoils and $P_{pl}$ starts to rise. As pleural pressure rises, alveolar pressure also increases. The transpulmonary pressure gradient narrows and alveoli begin to deflate. As the alveoli become smaller, alveolar pressure exceeds that at the airway opening.

DIF: Application    REF: p. 226    OBJ: 2

11. What forces must be overcome to move air into the respiratory system?
   12. tissue movement
   13. elastic forces of lung tissue
   14. airway resistance
   15. surface tension forces

a.  1, 2, and 3
b.  2 and 4
c.  4 only
d.  1, 2, 3, and 4

ANS: D

Elastic forces involve the tissues of the lungs and thorax, along with surface tension in the alveoli. Frictional forces include resistance caused by gas flow and tissue movement during breathing.

DIF: Application    REF: p. 226    OBJ: 3
12. What term is used to note the difference between inspiratory lung volume and expiratory lung volume at any given pressure?

a. alveolar aphasia
b. hysteresis
c. pleural pressure variance
d. transpulmonary pressures

ANS: B

Deflation of the lung does not follow the inflation curve exactly. During deflation, lung volume at any given pressure is slightly greater than it is during inflation. This difference between the inflation and deflation curves is called hysteresis.

DIF: Recall REF: p. 227 OBJ: 3

13. What is the effect of surface tension forces in the air-filled lung?
14. It increases the elastic recoil of the lung (promoting collapse).
15. It makes the lung harder to inflate than if it were filled with fluid.
16. It decreases the lung’s elasticity as volume increases.

a. 1 and 2
b. 2
c. 1 and 3
d. 1, 2, and 3
Less pressure is needed to inflate a fluid-filled lung to a given volume. This phenomenon indicates that a gas-fluid interface in the air-filled lung changes its inflation-deflation characteristics. The recoil of the lung is therefore a combination of tissue elasticity and these surface tension forces in the alveoli. During inflation, additional pressure is needed to overcome surface tension forces.

14. The presence of surfactant in the alveoli tends to do which of the following?
   a. decrease compliance
   b. decrease surface tension
   c. increase elastance
   d. increase resistance

ANS: B

A phospholipid called pulmonary surfactant lowers surface tension in the lung.

15. How is compliance computed?
   a. change in pressure/change in flow
   b. change in pressure/change in volume
   c. change in volume/change in flow
d. change in volume/change in pressure

ANS: D

Compliance of the lung ($C_L$) is defined as volume change per unit of pressure change. It is usually measured in liters per centimeter of water, as follows:

DIF: Application  REF:  p. 228  OBJ:  5

16. Normal lung compliance is approximately which of the following?

a. 0.01 L/cm H$_2$O  
b. 0.20 L/cm H$_2$O  
c. 2.00 L/cm H$_2$O  
d. 10.00 L/cm H$_2$O

ANS: B

Compliance of a healthy adult lung averages 0.2 L/cm H$_2$O or 200 ml/cm H$_2$O.

DIF: Recall  REF:  p. 229  OBJ:  5

17. A lung that loses elastic fibers (as in emphysema) would exhibit which of the following characteristics?
a. decreased airways resistance  
b. decreased pulmonary vascular resistance  
c. increased airway resistance  
d. increased pulmonary compliance  

ANS: D  

Increased compliance results primarily from loss of elastic fibers, which occurs in emphysema.  

DIF: Application  REF: p. 229  OBJ: 5  

18. A fibrotic lung would exhibit which of the following characteristics?  
a. decreased airway resistance  
b. decreased lung compliance  
c. decreased PVR  
d. decreased surface tension  

ANS: B  

The compliance curve of the patient with pulmonary fibrosis is flatter than the normal curve, shifted down and to the right. As a result, there is a smaller volume changes for any given pressure change (decreased compliance).  

DIF: Application  REF: p. 229  OBJ: 5
19. What occurs at a lung volume equivalent to the functional residual capacity (FRC)?
20. The forces of the chest wall and lungs are in balance.
21. Chest wall expansion is offset by lung contraction.
22. Opposing chest-wall-lung forces generate negative $P_{pl}$.

a. 1, 2, and 3  
b. 1 and 2  
c. 1 and 3  
d. 2 and 3

ANS: A

The lung–chest wall system may be compared with two springs pulling against each other. The chest wall spring tends to expand, whereas the lung spring tends to contract. At the resting level, the forces of the chest wall and lungs balance. The tendency of the chest wall to expand is offset by the contractile force of the lungs. This balance of forces determines the resting lung volume, or FRC. The opposing forces between the chest wall and lungs are partially responsible for the subatmospheric pressure in the intrapleural space.

DIF: Application  REF:  p. 225  OBJ:  4

20. At approximately what point during a maximum inspiration does the chest wall reach its natural resting level?

a. about 30% of the VC  
b. about 40% of the total lung capacity (TLC)  
c. about 70% of the VC  
d. about 90% of the VC
When lung volume nears 70% of the VC, the chest wall reaches its natural resting level.

ANS: C

21. Exhalation below the resting level requires active muscular effort in order to overcome what tendency?

a. the airways to collapse
b. the alveoli to expand
c. the chest wall to expand
d. the lungs to expand

ANS: C

In order to exhale below the resting level (FRC) muscular effort is required to overcome the tendency of the chest wall to expand.

DIF: Application  REF:  p. 230  OBJ:  4

22. In order to inspire to a lung volume greater than about 70% of TLC, the inspiratory muscles must overcome:
a. the recoil of the lungs
b. the recoil of both the lungs and the chest wall
c. the recoil of both the chest wall
d. the recoil of the alveoli

ANS: B

At the beginning of the breath, the tendency of the chest wall to expand facilitates lung expansion. When lung volume nears 70% of the VC, the chest wall reaches its natural resting level. In order to inspire to a lung volume greater than about 70% of TLC, the inspiratory muscles must overcome the recoil of both the lungs and the chest wall (see Figure 10-7).

DIF: Analysis   REF: p. 230   OBJ: 5

23. Total lung–thorax compliance in normal subjects is about what level?

a. 0.1 L/cm H₂O
b. 0.2 L/cm H₂O
c. 1.0 L/cm H₂O
d. 2.0 L/cm H₂O

ANS: A

In healthy adults, the compliance of the lungs and chest wall are approximately equal at 0.2 L/cm H₂O. However, because the lungs are contained within the thorax, the two systems act as springs pulling against each other. This reduces the
compliance of the system to approximately half that of the individual components, or 0.1 L/cm H$_2$O.

Impedance to ventilation by the movement of gas through the airways is called airway resistance.

24. What is the term for the impedance to ventilation caused by the movement of gas through the conducting system of the lungs?
   a. airway resistance
   b. lung compliance
   c. surface tension
   d. tissue elastance

ANS: A

25. How is airway resistance (Raw) computed?
   a. change in pressure/change in volume
   b. change in pressure/flow
   c. change in volume/ change in pressure
   d. change in volume/change in pressure

ANS: B
Airway resistance (Raw) is the ratio of driving pressure responsible for gas movement to the flow of the gas (\( \Delta P \)), calculated as follows:

26. Normal Raw is approximately which of the following?

a. 0.1 to 0.2 cm H\(_2\)O/L/sec  
b. 0.5 to 2.5 cm H\(_2\)O/L/sec  
c. 15.0 to 20.0 cm H\(_2\)O/L/sec  
d. 20.0 to 25.0 cm H\(_2\)O/L/sec

ANS: B

Airway resistance in healthy adults ranges from approximately 0.5 to 2.5 cm H\(_2\)O/L/sec.

27. Which of the following factors affects Raw?

28. pattern of gas flow (e.g., laminar versus turbulent)  
29. characteristics of the gas being breathed  
30. diameter and length of the airways  
31. variations in lung compliance

a. 1, 2, and 3  
b. 2 and 4  
c. 4 only
d. 1, 2, 3, and 4

ANS: A

Laminar flow is affected by gas flow, viscosity of the gas, tube radius and length. Turbulent flow is most affected by gas density and viscosity, linear velocity and tube radius.

DIF: Application  REF:  p. 231  OBJ:  6

28. According to Poiseuille’s law, which of the following statements are true if we wish to maintain a constant flow of gases?

a. Alveolar recruitment has its greatest effect on flow.

b. Halving the tube radius will require a 16-time increase in driving pressure.

c. Large jumps in driving pressure are needed to overcome airway narrowing.

d. The driving pressure varies directly with the airway circumference.

ANS: B

For gas flow to remain constant, delivery pressure must vary inversely with the fourth power of the airway’s radius. Reducing the radius of a tube by half requires a 16-fold pressure increase to maintain a constant flow. To maintain ventilation in the presence of narrowing airways, large increases in driving pressure may be needed. The energy necessary to generate these pressures can markedly increase the work of breathing.
29. Most of the drop in pressure due to frictional resistance to gas flow occurs in what region?

a. nose, mouth, and large airways
b. respiratory bronchioles
c. terminal bronchioles
d. terminal respiratory unit

ANS: A

Approximately 80% of the resistance to gas flow occurs in the nose, mouth, and large airways where flow is mainly turbulent.

30. Which of the following statements about Raw is true?

a. The greater the lung volume, the greater is the Raw.
b. The greater the lung volume, the less is the Raw.
c. As lung volume decreases toward RV, the Raw drops.
d. As lung volume increases toward TLC, the Raw rises.
ANS: B

The increase in airway diameter with increasing lung volume decreases airway resistance.

DIF: Application  REF:  p. 234  OBJ: 6

31. In healthy individuals, what may lead to airway collapse?

a. increased lung recoil
b. significantly decreased surfactant
c. maximal inspiration to TLC
d. forced exhalation to RV

ANS: D

In airways of healthy subjects, airway collapse occurs only with forced exhalation and at low lung volumes.

DIF: Application  REF:  p. 236  OBJ: 6

32. Which of the following statements about the equal pressure point (EPP) is true?

a. As gas travels from the EPP to the mouth, greater expiratory effort increases flow.
b. At the EPP, pressure inside the airway exceeds $P_{pl}$.
c. The EPP normally occurs at volumes greatly below the FRC.
d. **Upstream** from the EPP (toward the alveoli), $P_{pl}$ exceeds pressure in the

ANS: C

At some point along the airway, the pressure inside equals the pressure outside in the pleural space. This point is referred to as the EPP. Downstream from this point, pleural pressure exceeds the airway pressure. The resulting positive transmural pressure gradient causes airway compression and can lead to actual collapse. Airway compression increases expiratory airway resistance and limits flow. At the EPP, greater expiratory effort only increases pleural pressure, further restricting flow. In airways of healthy subjects, the EPP occurs only with forced exhalation and at low lung volumes.

DIF: Application  REF: p. 236  OBJ: 6

33. For healthy individuals at rest, which of the following statements about exhalation is true?

a. Exhalation will be passive, due to inspiratory stored potential energy.

b. Exhalation **inspiration** will only require 40% of the energy expended for

c. Exhalation will be the result of accessory respiratory muscle use.

d. Exhalation will generally take half the time of inspiration.

ANS: A
During normal quiet breathing, inhalation is active and exhalation is passive. The work of exhaling is recovered from potential energy “stored” in the expanded lung and thorax during inhalation.

34. In traditional physical terms, how is work defined?

a. force ´ distance  
b. force ´ time  
c. mass ´ acceleration  
d. mass ´ force

ANS: A  
Work = force ´ distance.

35. Which of the following formulas is used to compute the mechanical work of breathing?

a. change in pressure/flow  
b. change in pressure ´ change in flow  
c. change in pressure ´ change in volume  
d. change in volume/change in pressure
ANS: C

The mechanical work of breathing can be calculated as the product of the pressure across the respiratory system and the resulting change in volume:

DIF: Application  REF: p. 237  OBJ: 7

36. Why is the total mechanical work of breathing difficult to assess during spontaneous breathing?

a. Most volunteer subjects cannot understand the procedure used.
b. Respiratory muscle activity contributes to inflation resistance.
c. The respiratory muscles (diaphragm, etc.) must be paralyzed.
d. The subjects used to make the measurements must be unconscious.

ANS: B

The mechanical work of breathing cannot be measured easily during spontaneous breathing. This is because the respiratory muscles contribute to the resistance offered by the chest wall.

DIF: Application  REF: p. 238  OBJ: 7

37. On inspecting a volume–pressure curve of the lungs and thorax, an increase in the mechanical work of breathing above normal would always be indicated by which of the following?
a. decrease in the area of the volume–pressure curve
b. decrease in the slope of the volume–pressure curve
c. increase in the area of the volume–pressure curve
d. Increase in the slope of the volume–pressure curve

ANS: C

The larger the area defined by the pressure and volume changes, the greater is the amount of work being done.

DIF: Application   REF: p. 238   OBJ: 7

38. In health, about what proportion of the total work of breathing is attributable to frictional resistance to gas and tissue movement?

a. 

b. 

c. 

d. 

ANS: A

In healthy adults, approximately two thirds of the work of breathing can be attributed to elastic forces opposing ventilation. The remaining third is a result of frictional resistance to gas and tissue movement.
39. On inspecting a volume–pressure curve for a patient with restrictive lung disease, which of the following abnormalities would you expect to find?
   40. decrease in the slope of the volume–pressure curve
   41. increase in the area of the volume–pressure curve
   42. positive $P_{pl}$ during exhalation

a. 2 only
b. 1, 2, and 3
c. 1 and 2
d. 1 and 3

ANS: C

In restrictive lung disease, the area of the volume–pressure curve is greater because the slope of the static component (compliance) is less than normal.

40. Which of the following factors would tend to increase the elastic component of the work of breathing?
   41. decreased compliance of the lungs or thorax
   42. high frequencies of breathing
   43. increased $V_T$

a. 1 and 3
b. 1, 2, and 3
c. 2 and 3
d. 1 and 2
ANS: A

When changing from quiet breathing to exercise ventilation, healthy subjects adjust their tidal volumes and breathing frequencies to minimize the work of breathing. Similar adjustments occur in individuals who have lung disease (Figure 10-12). Patients with “stiff lungs”, i.e. decreased compliance, have increased elastic work of breathing. Large tidal volumes also increase the elastic component of work.

DIF: Application  REF:  p. 245  OBJ:  7

41. Which of the following factors would tend to increase the frictional component of the work of breathing?
   42. decreased compliance of the lungs or thorax
   43. high frequencies of breathing
   44. increased Raw

a. 1 and 2
b. 1, 2, and 3
c. 1 and 3
d. 2 and 3

ANS: D

In healthy individuals, the mechanical work of breathing depends on the pattern of ventilation. High breathing rates (and hence, high flows) increase frictional work. Patients who have airway obstruction (i.e., increased Raw) also experience increased frictional work of breathing.
42. In individuals with disorders characterized by an increased frictional work of breathing, such as emphysema, which of the following breathing patterns results in the minimum work?

a. rapid and deep breathing
b. rapid and shallow breathing
c. slow and deep breathing
d. slow and shallow breathing

ANS: C

Breathing slowly and using pursed lip breathing during exhalation minimize airway resistance and thus work of breathing in patients with emphysema.

43. All of the following will cause an increase in the pressure energy required for inspiration EXCEPT which one?

a. increased compliance
b. increased flow
c. increased resistance
d. increased volume
44. In a normal individual, what is the oxygen cost of breathing as a percentage of the body’s total oxygen consumption?

a. 5%
b. 10%
c. 20%
d. 35%

ANS: A

The oxygen cost of breathing in healthy individuals averages from 0.5 to 1.0 ml of oxygen per liter of ventilation. Given a normal minute ventilation of 5 L/min, the oxygen cost of breathing would be 2.5-5 ml out of a total oxygen consumption of 250 ml/min. This represents less than 5% of the oxygen consumption of the body.

DIF: Application  REF:  p. 238  OBJ:  7

45. Compared to a normal individual, when a patient with a severe obstructive impairment such as emphysema increases ventilation, which of the following occurs?
a. Carbon dioxide production falls as anaerobic metabolism increases.
b. Oxygen consumption increases at a faster rate than normal.
c. Oxygen consumption rises faster than carbon dioxide production.
d. The anaerobic threshold is reached later than normal.

ANS: B

In the presence of pulmonary disease (either obstructive or restrictive), the oxygen cost of breathing may increase dramatically with increasing ventilation (Figure 10-13). In an obstructive disease such as emphysema, increased ventilation causes the oxygen consumption of the respiratory muscles to increase rapidly.

DIF: Application REF: p. 239 OBJ: 7

46. Regional factors affecting the distribution of gas in the normal lung result in which of the following?

a. More ventilation goes to the apexes and lung periphery.
b. More ventilation goes to the apexes and lung core.
c. More ventilation goes to the bases and lung core.
d. More ventilation goes to the bases and lung periphery.

ANS: D

In upright individuals, these factors direct more ventilation to the bases and periphery of the lungs.
47. Which of the following statements are true about pressure differences in the upright lung?
48. $P_{pl}$ increases from lung apex to base.
49. The apical alveoli resting volume is less than at the base.
50. The transpulmonary pressure gradient is greatest at the apex.

a. 1 and 3
b. 1, 2, and 3
c. 2 and 3
d. 1 and 2

ANS: A

In an adult-sized lung (approximately 30 cm from apex to base), pleural pressure at the apex is approximately $-10\, \text{cm H}_2\text{O}$. At the base, pleural pressure is only about $-2.5\, \text{cm H}_2\text{O}$. Because of these differences, the transpulmonary pressure gradient at the top of the upright lung is greater than it is at the bottom.

48. During normal inspiration, which of the following occurs?

a. Alveoli at the apexes expand less than those at the bases.
b. Alveoli at the apexes expand more than those at the bases.
c. Alveoli at the bases expand less than those at the apexes.
d. Central alveoli expand more than those at the periphery.
Despite their higher volume, alveoli at the apices expand less during inspiration then alveoli at the bases or periphery. This is due to their respective positions on the pressure volume curves (Figure 10-14). The Apical alveoli are on the flatter or less compliant portion of the curve and thus for any change in pressure there is only a small change in volume. The alveoli in the lung base are on the steep part of the curve, so even small changes in pressure result in comparatively large changes in volume.

49. In a normal individual lying on the right side (right side down), which of the following conditions would be true?

a. Both lungs would receive nearly equal ventilation.
b. The left lung would receive the most ventilation.
c. The right lung would receive the most ventilation.
d. There is inadequate information to make a decision.

ANS: C

Lying on the side causes more ventilation to go to whichever lung is lower.
50. Given a constant resistance, how will increasing the compliance of a lung unit alter gas movement into and out of the alveolus?

a. Both filling and emptying will be slower.
b. The alveolus will fill and empty more quickly.
c. The alveolus will fill more quickly but empty more slowly.
d. The alveolus will fill more slowly but empty more quickly.

ANS: A

Lung units with high compliance have less elastic recoil than normal. These units fill and empty more slowly than normal units.

DIF: Application  REF:  p. 241  OBJ:  8

51. Which of the following statements apply to a lung unit with higher resistance than normal?

a. A given volume change will require less of a pressure change.
b. It will fill and empty more rapidly than a normal lung unit.
c. There will be less volume change for a given pressure change.
d. Volume to this area will remain the same under all conditions.

ANS: C

If the airway is obstructed, high resistance to gas flow can occur in a local area. The pressure drop across the obstruction may be substantial. Less driving pressure is available for alveolar inflation; thus there is less alveolar volume change.
52. Which of the following formulas are used to compute the time constant of a lung unit?

a. change in pressure ´ flow
b. compliance/resistance
c. resistance/elastance
d. resistance ´ compliance

ANS: D

The time constant is simply the product of each unit’s compliance and resistance:

53. Which of the following lung units would empty and fill most slowly?

a. a unit with high resistance and high compliance
b. a unit with high resistance and low compliance
c. a unit with low resistance and high compliance
d. a unit with low resistance and low compliance
Lung units have a short time constant when resistance or compliance is low. Lung units with short time constants fill and empty more rapidly than those with normal compliance and resistance. The inverse also holds true. Those units with a high resistance and compliance will fill and empty the most slowly.

54. For a given transpulmonary pressure gradient and inflation time, which of the following lung units would exhibit the greatest change in volume?

a. a unit with high resistance and low compliance
b. a unit with high resistance and normal compliance
c. a unit with normal resistance and low compliance
d. a unit with normal resistance and normal compliance

ANS: D

The ventilation going to lung units with either long or short time constants is less than that received by units with normal compliance and resistance.

55. In patients with small-airway disease breathing at higher than normal frequencies, what will NOT happen?

a. Dynamic compliance drops.
b. Oxygen consumption decreases.
c. The distribution of ventilation worsens.
d. The work of breathing increases.

ANS: B

Compliance of the lung appears to decrease as breathing frequency increases. This phenomenon is called frequency dependence of compliance. Compliance measured during breathing is dynamic as it includes pressure changes created by resistance to airflow. If dynamic compliance decreases as the respiratory rate increases, some lung units must have abnormal time constants. Any stimulus to increase ventilation, such as exercise, may redistribute inspired gas. Mismatching of ventilation and perfusion can result in hypoxemia, severely limiting an individual’s ability to perform daily activities. In addition the increased breathing frequency and decreased dynamic compliance may result in significant increases in oxygen consumption.

DIF: Analysis REF: p. 242 OBJ: 7

56. What is gas that is wasted during normal ventilation called?

a. alveolar ventilation
b. bronchial ventilation
c. conducting ventilation
d. dead space ventilation

ANS: D
For each breath, the gas left in the conducting tubes does not participate in gas exchange and is, in effect, wasted. Similarly, regional differences in ventilation cause some gas that does reach the alveoli to be wasted. This occurs in alveoli that have little or no perfusion. Ventilation occurring without perfusion defines dead space.

DIF: Recall  REF: p. 238  OBJ: 10

57. If a patient has a \( V_T \) of 370 ml and a respiratory rate of 20 breaths per minute, what is the minute ventilation?

a. 2.40 L/min  
b. 3.70 L/min  
c. 6.45 L/min  
d. 7.40 L/min  

ANS: D

Minute ventilation (exhaled) is denoted by \( E \), which is calculated as the product of frequency of breathing (\( f_B \)) times the expired tidal volume:

For example, our patient is breathing 20 breaths/min and has a \( V_T \) of 370 ml:

\[
= 20 \cdot 370 \text{ ml} \\
= 7400 \text{ ml/min, or 7.4 L/min}
\]

DIF: Analysis  REF: p. 243  OBJ: 10
58. A patient has a $V_T$ of 625 ml and a physiological dead space of 275 ml and is breathing at a frequency of 16 per minute. What is the alveolar ventilation ($V_A$)?

a. 3000 ml/min  
b. 4400 ml/min  
c. 5600 ml/min  
d. 7000 ml/min

ANS: C

Alveolar ventilation depends on tidal volume, dead space, and breathing rate. For this patient the respiratory rate is 16, $V_T$ of 625 ml, and dead space ($V_D$) of 275 ml. The alveolar ventilation is calculated as follows:

$$V_A = 16 \times (625 \text{ ml} - 275 \text{ ml}) = 16 \times 350 = 5600 \text{ ml/min or 5.6 L/min}$$

DIF: Analysis  
REF: p. 243  
OBJ: 11

59. A normal 150-lb man is breathing at a rate of 17 with a tidal volume of 450 ml. By estimation, what is his approximate alveolar ventilation?

a. 7.65 L/min  
b. 5.10 L/min  
c. 3.85 L/min  
d. 2.60 L/min

ANS: B
$V_{Danat}$ averages approximately 1 ml per pound of ideal body weight (2.2 ml/kg). For a subject who weighs 150 lb (68 kg), $V_{Danat}$ is approximately 150 ml. For our patient the $V_T$ is 450, the RR is 17, and we'll say his actual weight is his ideal body weight so 150-lb = 150 ml $V_D$.

$$V_A = f(V_T - V_D)$$

$$V_A = 17(450 \text{ ml} - 150 \text{ ml})$$

$$V_A = 17(300 \text{ ml}) = 5100 \text{ ml or 5.1 L}$$

DIF: Analysis REF: p. 243 OBJ: 11

60. Blockage of the pulmonary arterial circulation to a portion of the lung would cause which of the following?

a. decrease in anatomical dead space
b. decrease in physiologic dead space
c. increase in alveolar dead space
d. increase in anatomical dead space

ANS: C

A pulmonary embolus blocks a portion of the pulmonary circulation. This obstructs perfusion to ventilated alveoli, creating alveolar dead space.

DIF: Application REF: p. 244 OBJ: 10

61. In what portion of the lungs does alveolar dead space normally occur?
62. Which is the correct formula to calculate the alveolar minute ventilation of a spontaneously breathing subject?

a. \( f \cdot V_{DS}/V_T \)

b. \( f \cdot V_T \)

c. \( f \cdot (V_T - V_{Dphys}) \)

d. \( f \cdot (V_T + V_{Dphys}) \)

ANS: C

Physiologic dead space includes both the normal and abnormal components of wasted ventilation. \( V_{Dphy} \) is the preferred clinical measure of ventilation efficiency. Measuring \( V_{Dphy} \) more accurately assesses alveolar ventilation:
63. In clinical practice measuring the physiologic dead space ventilation is achieved by using which formula?

a. Bernoulli’s equation
b. modified Bohr equation
c. modified Shunt equation
d. Reynold’s equation

ANS: B

The ratio is then calculated using a modified form of the Bohr equation, which assumes that there is no CO₂ in inspired gas:

64. In normal individuals, approximately what fraction of the Vₜ is wasted ventilation (does not participate in gas exchange)?

a. 
b. 
c. 
d. 
ANS: A

In the healthy adult, physiologic dead space is approximately one third of the tidal volume.

DIF: Recall REF: p. 244 OBJ: 11

65. Which of the following diseases or disorders is most likely to result in an increased $V_D/V_T$ ratio?

a. atelectasis
b. pneumonia
c. pulmonary embolus
d. pulmonary fibrosis

ANS: C

$V_D/V_T$ increases with diseases that cause significant dead space, such as pulmonary embolism.

DIF: Application REF: p. 244 OBJ: 11

66. What will happen if the rate of breathing increases without any change in total minute ventilation ($E_{\text{constant}}$)?

a. The dead space ventilation per minute will decrease.
b. The $A$ per minute will decrease.
c. The $A$ per minute will increase.
d. The \( A \) per minute will remain constant.

ANS: B

High respiratory rates and low tidal volumes result in a high proportion of wasted ventilation per minute (low \( A \)).

DIF: Application      REF:  p. 244      OBJ: 10

67. Which of the following ventilatory patterns would result in the MOST wasted ventilation per minute (assume constant physiologic dead space)?

**Frequency Tidal Volume**

a. 

b. 

c. 

d. 

ANS: D

High respiratory rates and low tidal volumes result in a high proportion of wasted ventilation per minute (low \( A \)).

DIF: Analysis      REF:  p. 244      OBJ: 11
68. Which of the following ventilatory patterns would result in the greatest A per minute (assume constant dead space)?

Frequency Tidal Volume

a. 

b. 

c. 

d. 

ANS: A

In general, the most efficient breathing pattern is slow, deep breathing.

DIF: Analysis       REF:  p. 244       OBJ: 11

69. How can the body effectively compensate for an increased $V_{Dphy}$?

a. decreased drive to breath

b. decreased respiratory rate

c. increased respiratory rate

d. increased tidal volume

ANS: D

Effective compensation for increased $V_{Dphy}$ requires an increased tidal volume.
70. Under resting metabolic conditions, how much carbon dioxide does a normal adult produce per minute?

a. 150 mL/min  
b. 200 mL/min  
c. 250 mL/min  
d. 300 mL/min

ANS: B

Under resting metabolic conditions, a normal adult produces approximately 200 mL of carbon dioxide per minute.

71. For carbon dioxide levels to remain constant during exercise, which of the following factors must be elevated?

a. alveolar ventilation  
b. dead space ventilation  
c. hemoglobin  
d. / ratio

ANS: A
The partial pressure of carbon dioxide in the alveoli and blood is directly proportional to its production ($CO_2$) and inversely proportional to its rate of removal by alveolar ventilation ($A$):

DIF: Application  REF:  p. 245  OBJ:  10

72. Hypoventilation is defined as:

a. decreased tidal volume  
b. low blood oxygen level  
c. very slow respiratory rate  
d. elevated blood carbon dioxide level

ANS: D

Ventilation that does not meet metabolic needs (resulting in respiratory acidosis) is termed “hypoventilation.” Hypoventilation is indicated by the presence of an elevated PaCO$_2$.

DIF: Application  REF:  p. 245  OBJ:  10

73. What is ventilation that is insufficient to meet metabolic needs called?

a. hypoventilation  
b. hyperventilation  
c. hyperpnea  
d. hypopnea
Ventilation that does not meet metabolic needs (resulting in respiratory acidosis) is termed hypoventilation. Hypoventilation is indicated by the presence of an elevated PaCO₂.

74. A patient has a PCO₂ of 56 mm Hg. Based on this information, what can be concluded?

a. The patient is hyperventilating.
b. The patient is hypoventilating.
c. The patient’s breathing rate is fast.
d. The patient’s Vₜ is low.

ANS: B

Ventilation that does not meet metabolic needs (resulting in respiratory acidosis) is termed hypoventilation. Hypoventilation is indicated by the presence of an elevated PaCO₂.

If alveolar ventilation increases, the lungs may remove carbon dioxide faster than it is being produced. In this case, PaCO₂ will fall below its normal value of 40 mm Hg, and pH will rise (i.e., respiratory alkalosis).
75. Given a constant carbon dioxide production, how will changing the level of $V_A$ affect the PaCO$_2$?

a. A decrease in $A$ will decrease PaCO$_2$.
b. An increase in $A$ will decrease PaCO$_2$.
c. An increase in $A$ will increase PaCO$_2$.
d. PaCO$_2$ is unaffected by changes in $A$.

ANS: B  DIF: Analysis  REF: p. 246  OBJ: 11

76. What is ventilation in excess of metabolic needs called?

a. hyperpnea  
b. hyperventilation  
c. hypopnea  
d. hypoventilation

ANS: B

Ventilation in excess of metabolic needs is termed hyperventilation.

DIF: Application  REF: p. 246  OBJ: 10
77. What is the normal increase in ventilation that occurs with increased metabolic rates called?

a. hyperpnea  
b. hyperventilation  
c. hypopnea  
d. hypoventilation

ANS: A

The increase in ventilation that occurs with increased metabolic rates is termed hyperpnea.

DIF: Application  REF: p. 246  OBJ: 10

78. What is the single best indicator of the adequacy or effectiveness of A?

a. PaO₂  
b. PAO₂  
c. PaCO₂  
d. VT

ANS: C  
DIF: Application  REF: p. 246  OBJ: 10

79. All of the following happen at the beginning of inspiration, except:
a. Inspiratory muscles expand thorax.
b. Alveolar expansion decreases $P_{alv}$ below zero.
c. Alveolar expansion increases $P_{alv}$ above zero.
d. Alveolar filling slows as $P_{alv}$ approaches $P_{ao}$.

ANS: C

For a spontaneously breathing subject, in the beginning of inspiration, PA is subatmospheric compared to PAO causing air to flow into the alveoli (Alveolar expansion decreases $P_{alv}$ below zero).

DIF: Application  REF:  p. 224  OBJ: 1

80. All of the following are correct about elastic opposition to ventilation, except:

a. Elastic and collagen fibers provide resistance to lung stretch.
b. With changes in transpulmonary pressure, all of the applied pressure opposes elastic forces.
c. Elastic properties of the lungs and chest wall oppose inflation.
d. A small amount of pressure causes greater stretch until maximum inflation is reached.

ANS: D

In the respiratory system, inflation stretches tissue. The elastic properties if the lungs and chest wall oppose inflation. To increase lung volume, pressure must be applied. Greater pressure causes greater stretch until maximum inflation is reached.
81. Where is Raw said to be the highest in the airway of the human body?

a. terminal bronchioles  
b. carina  
c. left lower lobe  
d. nose, mouth and large airways

ANS: D

Approximately 80% of the resistance to gas flow occurs in the nose, mouth, and large airways, where flow is mainly turbulent. Only about 20% of the total resistance to flow is attributable to airways smaller than 2 mm in diameter, where flow is mainly laminar.

82. Which of the following causes gas to flow into and out of the alveoli during breathing?

a. transrespiratory system pressure ($P_{TR}$)  
b. intrapleural pressure ($P_{pl}$)  
c. transpulmonary pressure ($P_{TP}$)  
d. and transmural pressure ($P_{tm}$)
ANS: A

Transrespiratory pressure ($P_{TR}$) gradient causes gas to flow into and out of the alveoli during breathing.

DIF: Application  REF: p. 225  OBJ: 2

83. What is used for setting optimal PEEP on a ventilator?

a. Pressure-volume curve
b. Flow-volume curve
c. Patient’s height and weight
d. The disease state the patient is in.

ANS: A

Pressure-volume curve is used for setting optimal PEEP.