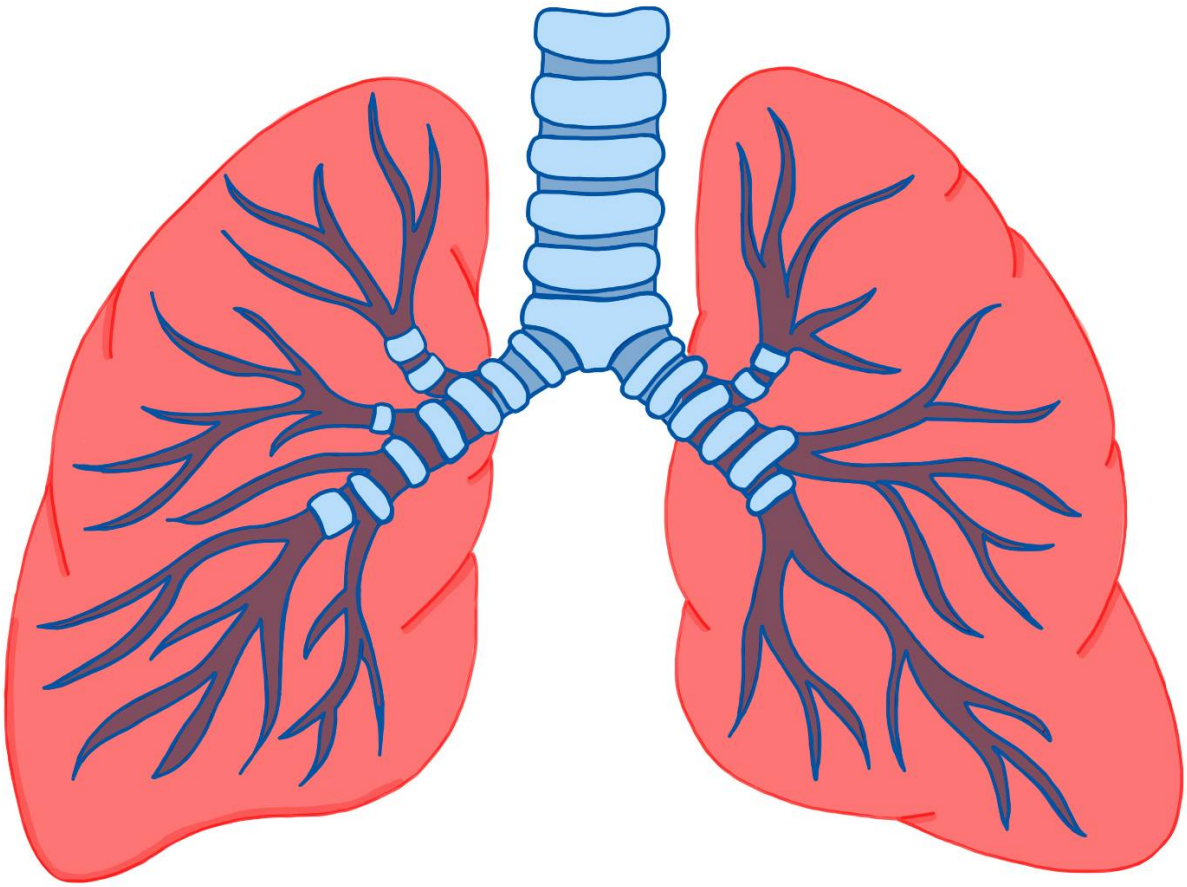


RESPIRATORY PHYSIOLOGY
ANSWER KEY

SECTION 1 – MECHANICS OF VENTILATION

1) Select the correct statement(s) regarding lung volumes and capacities

a) Tidal volume is the amount of air inspired or expired during *forced* ventilation

b) IRV and ERV are used during *quiet* ventilation

c) VC and FVC have different values

d) The amount of air remaining in the lungs after normal expiration is called FRC and has a value of 2,4 L

e) None of the above

2) Which are the only lung volumes and capacities <u>NOT</u> measurable with spirometry? (tip: draw the mneumonic "m and M")

a) RV, FRC and VC

b) RV, VC and TLC

c) RV, FRC and TLC

d) All of the lung volumes and capacities are technically measurable with spirometry

e) It depends on the patient

3) What is/are the correct formula(s) for calculation of lung capacities.

a) VC = V_T + IRV + ERV

b) TLC = VC + RV

c) TLC = FRC + IC

d) A and C are correct

e) All of the above

4) Select the correct statement regarding ventilation.

a) Alveolar ventilation is greater than minute ventilation

b) The conducting zone may sometimes participate in gas exchange

c) The respiratory zone is composed of terminal bronchioles, respiratory bronchioles, alveolar ducts and alveolar sacs

d) In all cases, the quantity of the physiological dead space is around 1/3 of the tidal volume

e) None of the above

5) What is the difference between ventilation and respiration?

a) There is no difference between ventilation and respiration

b) Ventilation refers to the mechanical aspect of breathing

c) Respiration refers to everything from the mechanical aspect of breathing to the usage of oxygen in oxidative phosphorylation

d) B and C are correct

e) None of the above

6) Select the correct statement regarding the muscles of ventilation.
a) Contraction of the internal intercostal muscles increases the anteroposterior- and horizontal diameter of the thoracic cavity
b) Inspiration is always an active process
c) In some individuals, quiet expiration might be an active process
d) A and B are correct
e) None of the above

7) Select the correct statement regarding intrapleural pressure.
a) The normal value of the intrapleural pressure in a resting adult is - 5 cm H_20
b) The negative value is created by the lung and the chest wall pulling on the parietal- and visceral pleural, respectively
c) The intrapleural pressure may become positive in a pneumothorax
d) A and C are correct
e) All of the above

8) Select the correct statement regarding elastic recoil of the lung.
a) Elastic recoil is determined by LaPlace law and the inherent compliance of the lung
b) Surfactant is produced by type I pneumocytes
c) The major function of surfactant is to destroy the elastic fibers of the lung
d) When elastic recoil is greater than the intrapleural pressure, the lung will collapse
e) None of the above

9) At which point during the ventilatory cycle is the highest flow of air into the alveoli?
a) Beginning of inspiration
b) Middle of inspiration
c) End of inspiration
d) The air flow is equally high during the whole inspiratory phase
e) A and B are correct

SECTION 2 – RESPIRATION

1. Which factor(s) are the main determinants of the partial pressure of oxygen in the alveolus?
a) PA_{CO2}
b) Fi_{O2}
c) P_{atm}
d) P_{H2O}
e) B and D
f) B and C

2) Which of the following equations best describes the amount of oxygen present in the alveolus?
a) $PA_{O2} = Fi_{O2} \times (P_{atm} - P_{H20}) - (P_{CO2}/R)$
b) $Pa_{O2} = Fi_{O2} \times (P_{atm} - P_{H20}) - (P_{CO2}/R)$
c) $PA_{O2} = Fi_{O2} \times (P_{atm} - P_{H20})$
d) $PA_{O2} = Fi_{O2} \times (P_{atm} - P_{H20}) \times (P_{CO2}/R)$

Explanation: The amount of oxygen present in the alveolus is determined by: the atmospheric pressure, fraction of inspired oxygen, the partial pressure of water and carbon dioxide. Note that the partial pressure of oxygen in the alveolus is called PAO2 (big letter A), not PaO2. PaO2 describes the partial pressure of oxygen present in **blood**.

3) What are the effects of supplemental oxygen?
a) It increases the P_{atm}
b) It increases the Fi_{O2}
c) Administration of 1 L/min of oxygen will increase the Fi_{O2} to 25%
d) Administration of 1 L/min of oxygen will increase the P_{atm} to 25%
e) A and D
f) B and C

Explanation: Administering supplemental oxygen to patients will increase their fraction of inspired oxygen. If a patient receives 1L/min of oxygen on a nasal cannula, their fraction of inspired oxygen will increase from 21% (fraction of oxygen in room air) to 25%. According to the alveolar gas equation, this will increase the amount of oxygen present in the alveoli.

4) Select the correct statement(s) regarding oxygen transport from the alveolus to the pulmonary capillary.
a) The direction of diffusion is determined by the partial pressure gradient
b) Gases will diffuse from an area of lower partial pressure to an area of higher partial pressure
c) Oxygen uploads directly on to hemoglobin during diffusion into the pulmonary capillary
d) Only gases bound to hemoglobin can participate in the partial pressure gradient
e) A and C
f) A and D

Explanation: Gases will always diffuse from an area of higher partial pressure to an area of lower partial pressure. Oxygen dissolves into the blood *before* it uploads to hemoglobin. Only dissolved gases (e.g., PaO2) can participate in the partial pressure gradient.

5) Select the correct statement(s) regarding fick´s law of diffusion.
a) It describes how fast a gas will diffuse across a semipermeable membrane
b) It is dependent on surface area of the lung and size of the interstitial space

c) Pathologies which result in destruction of alveoli will decrease the diffusion rate of gases
d) It is dependent on the solubility and surface area of gases
e) A, B and C
f) B and C

Explanation: Ficks law describes how fast a gas will diffuse across a permeable membrane. It is dependent on the surface area of the lung, size of the interstitial space (same as membrane thickness), partial pressure gradient and the solubility of the gas (not surface area of the gas). Pathologies which lead to destruction of the alveoli (e.g., emphysema) will decrease the surface area of the lung (the main determinant of lung surface area is the number of alveoli). According to fick´s law, decreased surface area will decrease the rate of gas diffusion across the alveoli.

6) Which of the following gases is most soluble?
a) Oxygen
b) Carbon dioxide
c) Carbon monoxide
d) Nitrogen

Explanation: CO > CO2 >> O2 > N_2

7) Select the correct statement(s) regarding the total oxygen content of blood.
a) The majority of oxygen is dissolved in blood
b) The majority of oxygen is bound to hemoglobin
c) The total oxygen content is determined by dissolved oxygen, hemoglobin saturation and hemoglobin concentration
d) The total oxygen content is determined by dissolved oxygen, hemoglobin saturation, hemoglobin concentration and cardiac output
e) B and C
f) B and D

8) "A young athlete comes to your office for her yearly checkup. She tells you that she has no complaints and is otherwise feeling healthy. As a part of the checkup, you take a blood sample to determine the hemoglobin level of the patient. When the results come back you see that her hemoglobin level is slightly decreased. Select the correct statement(s) regarding the oxygen delivery and symptoms in this patient."
a) The oxygen delivery will be decreased
b) Oxygen delivery will be maintained due to the ability of young patients to increase their hemoglobin production
c) Oxygen delivery will be maintained due to the ability of young patients to compensate by increasing their cardiac output
d) The patient may have no other signs of anemia than a slight increase in heart rate
e) The patient will be pale
f) B and E
g) C and D

Explanation: According to the oxygen delivery equation, decreases in hemoglobin concentration will decrease the oxygen delivery to the tissues. However, young and healthy patients can compensate for small drops in hemoglobin concentration by increasing their cardiac output. A way to increase the cardiac output is to increase heart rate (CO = HR x SV). Larger drops in hemoglobin is more likely to result in signs such as pallor (paleness).

9) Select the correctly matched pairs.

a) ↑ CO2 – Right shift

b) ↓ Temperature – Right shift

c) ↑ pH – Left shift

d) Bohr effect – Left shift

e) ↑H+ – Right shift

f) ↓ 2,3 BPG – Left shift

10) Select the correct statement(s) regarding the P_{50} value.

a) It is the partial pressure of oxygen at which hemoglobin is 50% saturated

b) It is the partial pressure of carbon dioxide at which hemoglobin is 50% saturated

c) It is increased with right shifts

d) It is increased with left shifts

e) A and C

F) A and D

11) In the transport of CO2 from the tissues to the lungs, which of the following occurs in venous blood?

a) Conversion of CO_2 and H_2O to H^+ and HCO_3^- in red blood cells

b) Shifting of HCO_3 into the RBCs from plasma in exchange for Cl^-

c) Binding of HCO_3^- to hemoglobin

d) Conversion of HCO_3^- and H^+ to CO_2 and H_2O

12) Most of the CO_2 transported in blood is:

a) Dissolved in plasma (Pa_{CO2})

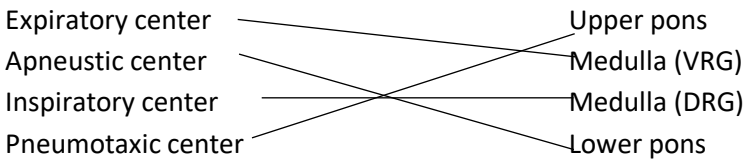
b) In the form of carbaminohemoglobin

c) Transported as HCO_3^-

d) Combined with chloride

SECTION 3 – CONTROL OF BREATHING

1) Connect the correct center with its location in the brain stem.



2) Which of the following does NOT stimulate the inspiratory center?

a) Muscle and joint receptors

b) Pneumotaxic center

c) Glomus type I cells

d) Central chemoreceptors

3) Which medullary center contains both inspiratory and expiratory neurons?

a) The center located in the dorsal respiratory group

b) The center that inhibits the apneustic center

c) The center that is inactive during normal quiet breathing

d) The center that maintains the rate of inspiration

4) Which of the following causes inhibition of the apneustic center?

a) Apneusis

b) Passive expiration

c) Activation of inspiratory center

d) Increased action potential via the phrenic nerve

5) True or False.

Aortic bodies are stimulated when the PaO_2 is 70 mmHg **T / F**

Central chemoreceptors are directly stimulated by CO_2 **T / F**

Irritant receptors are also called rapidly adapting receptors **T / F**

Hypoventilation leads to ↓ Pa_{CO2} **T / F**

Explanation: Both aortic and carotid bodies are stimulated when PaO2 is below 60 mmHg
CO2 indirectly stimulates the central chemoreceptors, H+ stimulates directly
Hypoventilation leads to ↑PaCO2

6) Choose the correct statement.

a) C-fibers are also known as juxtaglomerular receptors

b) The Hering-Breuer reflex is activated when V_T > 1,5 liters

c) Lung stretch receptors increase respiratory rate

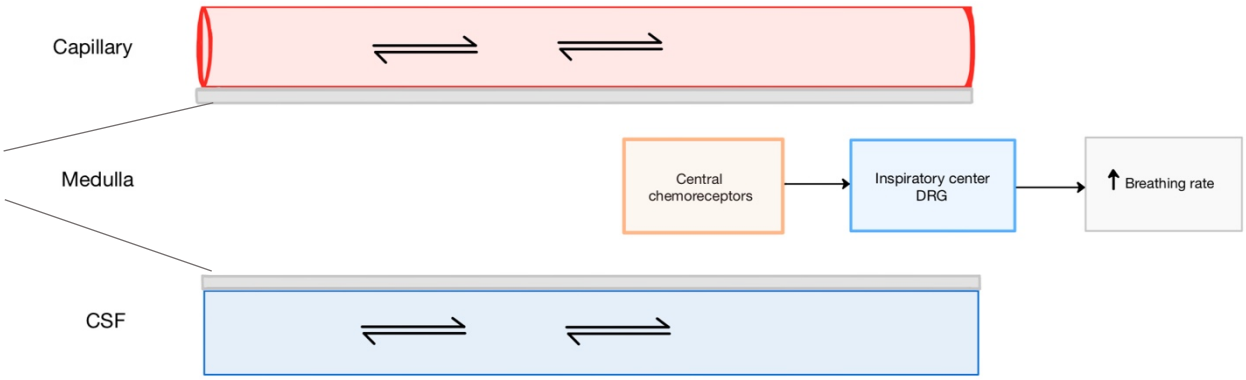
d) Rapidly adapting receptors are found in airway smooth muscle

7) Fill in the blanks.

a) Symptoms of **apneusis** are prolonged deep inspiration followed by a brief, insufficient expiration. This is caused by damage to the **pneumotaxic** center.

b) Hyperventilation leads to **decreased** Pa_{CO2}
c) Hypoventilation leads to **increased** Pa_{CO2} and **decreased** Pa_{O2}
d) The posterior neurons of the DRG receive information from the **Hering-Breuer reflex**

8) Finish the central chemoreceptor activation pathway.
See illustration in booklet



9) Fill in the blanks.
The central chemoreceptors are **indirectly** stimulated by CO_2 and **directly** stimulated by H^+ (decreased pH).

10) Fill in the table.
See table in booklet

		Joint and muscle receptors		**Juxtacapillary[2] receptors**
Type	Mechanoreceptor		Rapidly adapting receptors	
Location		Joints and muscles		Alveolar walls
Stimulation	Distension of the lungs		Noxious chemicals and particles	- __ Blood volume - __ Interstitial fluid volume
Effect on respiratory rate				
Comments/ reflexes	Hering-Breuer reflex		Coughing reflex	

SECTION 4 – INTEGRATIVE FUNCTIONS

1) Fill in the correct answer.
During exercise, there is _____ (**increased**/decreased) muscle exertion. The working muscle requires O_2 to produce ____ (lactic acid/**ATP**), resulting in __ (**increased/**decreased) O_2 demand.

2) What receptor is activated during exercise (that is inactive during normal, quiet breathing)?
a) Dorsal Respiratory Group
b) Pneumotaxic center
c) Central chemoreceptors
d) Ventral Respiratory Group

3) Explain why perfusion (Q) in the lungs increases with increased ventilation.
During exercise, cardiac output increases up to 6 times of normal volume (5L/min 30 L/min). The increase in blood volume leads to increased blood pressure, pumping larger amounts of blood through the circulation to meet the oxygen demands of the muscle tissue. Increased CO leads to increase in preload and increased perfusion of the lungs. Increased ventilation + increased perfusion → increased gas exchange.

4) Select the correct response to exercise.
a) PaO_2 increases
b) Venous PCO_2 has no change
c) $PaCO_2$ decreases
d) Tissue PO_2 decreases

5) True or false.
a) 2,3-BPG increases oxygen affinity to hemoglobin **T/F**
b) In response to increased oxygen demand more 2,3-BPG is produced **T/F**
c) The Bohr effect refers to a change in oxygen-hemoglobin dissociation curve due to changes in CO_2, pH, and 2,3-BPG **T/F**
e) O_2-Hemoglobin dissociation curve shifts to the right during exercise **T/F**

Explanation: 2,3-BPG increases oxygen affinity to haemoglobin, only CO2 and pH is related to the Bohr effect

6) Place the correct responses to acute changes and acclimatization to high altitude. The responses may be used once, twice or not at all.

Acute changes	Acclimatization
↓ PaO_2, hyperventilation, respiratory alkalosis, normal hemoglobin concentration, ↓hemoglobin saturation	↓ PaO_2, hyperventilation, normal pH, ↑ hemoglobin concentration, normal hemoglobin saturation

↓ PaO_2, ↑ $PaCO_2$, hyperventilation, hypoventilation, respiratory alkalosis, respiratory acidosis, normal pH, ↓ Hb saturation, ↑ Hb saturation, normal Hb concentration, ↑ Hb concentration, ↓ Hb concentration

7) Choose the correct statement.

a) Exposure to high altitude leads to hypoventilation

b) Decrease in atmospheric pressure leads to increased hemoglobin saturation

c) pH stabilized back to normal during acclimatization due to increased HCO_3 excretion from the kidneys

d) Exposure to high altitude leads to left shift of the oxygen-hemoglobin dissociation curve

8) Choose the correct statement describing hypoxemia.

a) Respiratory rate above 20 breaths/minute

b) Insufficient levels of Pa_{O2}

c) Respiratory rate below 12 breaths/minute

d) Insufficient oxygen at the cellular level