Respiratory System

Part A – Multiple Choice

1. C
2. B
3. B
4. B
5. D
6. B
7. C
8. D
9. A
10. B
11. D
12. D
13. B
14. D
15. D
16. A
17. D
18. D
19. C
20. D
21. C
22. A
23. A
24. B
25. D

Part B – Written Answers

Note: The answers provided here are correct, but they may NOT be the only possible answers.

1. a. Hemoglobin transports oxygen in the form of oxyhemoglobin (HbO_2). A major blood vessel where this can be found is the pulmonary vein.
   Hemoglobin also transports CO_2 in the form of carbaminohemoglobin ($HbCO_2$). A major blood vessel where this can be found is the vena cava.
   As well, hemoglobin transports H^{1+} in the form of reduced hemoglobin (HHb). This can be found in the vena cava as well.

   b. Hemoglobin's transport abilities are affected by both temperature and pH. These, coupled with the relative availability of O_2 and CO_2 in the plasma dictate what hemoglobin transports. The metabolic activity of body cells (such as muscle tissue) generates a little heat, warming the blood slightly (about one ^oC). Also, the pH is slightly lowered due to the presence of metabolic acid, carbonic acid, which dissociates to release H^{1+}. The impact of these changes and the fact that CO_2 is more plentiful than O_2, mean that Hb releases the O_2 it was carrying and bonds to either CO_2 or H^{1+}.

   In the lung capillaries, the situation is reversed. Oxygen is more plentiful than CO_2, the temperature is slightly lowered and the pH is slightly higher (due to the absence of metabolic activity and acids). Under these conditions, Hb releases the CO_2 or H^{1+} it was carrying and readily accepts O_2.

2. Inhalation is triggered at the medulla oblongata primarily by an elevated level of CO_2 and H^{1+} in blood that goes through it. Its response is to generate nerve impulses to the diaphragm and intercostal muscles (between the ribs). Both of these muscles contract separately, but in unison. The contraction of the diaphragm causes it to shorten into a lowered position (flatten out) and the contraction of the rib muscles cause them to shorten, which moves the rib cage up and out. Both of these actions increase the volume of the thoracic cavity. The thoracic cavity is lined by pleural membranes, which "suction" the lung tissue to the surfaces of the expanded thoracic cavity. This expanded volume creates a vacuum effect (negative pressure), causing air to enter the respiratory passageway. The two layers of

pleural membranes are kept moist and they facilitate the movement of the lung tissue against the inner surface of the rib cage without abrasion as the lungs expand. Note that inhalation is "active" (uses ATP).

Exhalation is triggered by the expanded alveoli of the lungs. They are equipped with nerve receptors that are sensitive to stretch. During the expansion of the lungs, a stretch threshold is reached, which generates an impulse to the medulla oblongata preventing it from continuing its stimulation of the diaphragm and intercostal muscles. No longer stimulated, these muscles relax and return to their elongated positions (domed diaphragm and lowered rib cage). This action puts pressure on the lung tissue, which slides over the inner surfaces of the thoracic cavity as they deflate causing air to move out of the respiratory passageway. Note that exhalation is "passive" (doesn't use ATP).

3. a. In systemic capillaries, carbonic anhydrase catalyzes the reaction between water and carbon dioxide to produce carbonic acid. Carbonic acid readily dissociates into the ions H^{1+} and HCO_3^{1-}. This reaction is summarized as:

b. In pulmonary capillaries, carbonic anhydrase catalyzes the reverse of the reaction it did in the systemic capillaries, namely the breakdown of carbonic acid, which is reformed from ions, into water and carbon dioxide. This reaction is summarized as:

4. It is critical that the pH doesn't vary very much from 7.38. There is a slight lowering of the pH (to about 7.35) in tissue capillaries (site of internal respiration) because of the reaction between carbon dioxide and water (under the influence of carbonic anhydrase (see #3a above). The products of this reaction (carbonic acid and free hydrogen ions) lower the pH. It is held in check in two ways. Firstly, the H1+ does not remain free as it bonds to hemoglobin, forming reduced hemoglobin. Secondly, the bicarbonate ions buffer the blood. They can either accept or release hydrogen ions as required to maintain a steady pH.