Solutions to Homework Assignment – Module 13

1. [20 points] Describe/discuss/explain the mechanism(s) by which oxygen is transported from alveoli to cells (in tissue).

This process can be (arbitrarily) broken down into 3 distinct steps: (1) diffusion of O_2 from alveolar air to pulmonary capillary blood, (2) carriage of O_2 in blood from pulmonary capillaries to tissue capillaries and (3) diffusion of O_2 from tissue capillaries to tissue cells.

Diffusion of O_2 from alveolar air to pulmonary capillary blood

P_{O2} in alveolar air is ≈100 mmHg; in blood entering pulmonary capillaries it is ≈40 mmHg (B&L[6+], Figure 22-1; B&L[7], Figure 23.8; VSL[14], Figure 13.21). So – there is a pressure gradient to drive oxygen, by simple diffusion, between the alveolar space and pulmonary capillary blood. The oxygen has to diffuse through the alveolar wall and the pulmonary capillary wall (Video 1, Slides 2, 3, 4). See also Video 1, Slide 5.

Carriage of O_2 in blood from pulmonary capillaries to tissue capillaries

Assuming no pathology, by the time blood passes through the pulmonary capillaries the blood P_{O2} has equilibrated with the alveolar P_{O2} (B&L[6+], Figure 22-11; B&L[7], Figure 23.8). Once O_2 has diffused into pulmonary capillary blood it is carried dissolved (maybe ≈2%; in plasma and in the RBCs) or bound to hemoglobin (≈97-98%; in the RBCs) – see Video 2, Slide 2.

Diffusion of O_2 from tissue capillary blood to tissue cells

At the tissue capillaries there is a partial pressure gradient for oxygen favoring diffusion from tissue capillaries to tissue interstitium (and thence to cells) – see Video 2, Slide 2; VSL[14], Figure 13.21. As well, the affinity of hemoglobin for oxygen at the tissue capillaries is less than at the pulmonary capillaries because of the elevated temperature and P_{CO2} (Böhr effect) at the tissue capillaries WRT the pulmonary capillaries (Video 2, slides 8, 9). Once in the tissue interstitium oxygen diffuses to and enters tissue cells.

2. [20 points] Describe/discuss/explain the mechanism(s) by which carbon dioxide is transported from cells (in tissue) to alveoli.

This process can be (arbitrarily) broken down into 3 distinct steps: (1) diffusion of CO_2 from tissue cells to tissue capillary blood, (2) carriage of CO_2 in blood from tissue capillaries to pulmonary capillaries and (3) diffusion of CO_2 from pulmonary capillaries to alveolar air.

Diffusion of CO_2 from tissue cells to tissue capillary blood

At the tissue capillaries there is a partial pressure gradient for CO_2 favoring diffusion (of CO_2) from tissue cells to interstitium to tissue capillary blood (VSL[14], Figure 13.21; Video 2, Slide 3). As well, the affinity of hemoglobin for

Rev 0, 4/7/17 - adapted from Spring 2016
Rev 1, 11/23/17 - update refs to include B&L[7]
Rev 2, 8/3/18 - update to 601; minor text changes so that question text matches Assignment. Minor clarifications to responses.

CO_2 is "high" because of the "low" partial pressure of oxygen (≈40 mmHg) in tissue capillary blood (Video 2, Slide 10). So – the diffusion of CO_2 from the tissue cells to tissue capillary blood is favored.

Carriage of CO_2 in blood from tissue capillaries to pulmonary capillaries
CO_2 is carried in venous blood (from tissue capillaries to pulmonary capillaries) in 3 forms: (1) dissolved (in plasma and in RBCs), (2) as carbamino compounds (in plasma and in RBCs) and (3) as bicarbonate ion (in plasma and in RBCs) - see Video 2, Slides 3, 4; West[10], Figure 6.5.

Diffusion of CO_2 from pulmonary capillaries to alveolar air
At the pulmonary capillaries there is a partial pressure gradient for CO_2 favoring diffusion of CO_2 from pulmonary capillary blood (P_{CO2} ≈46 mm Hg) to alveolar air (P_{CO2} ≈40 mmHg – see VSL[14], Figure 13.21). As well, the increase in P_{O2} that takes place in the pulmonary capillaries favors off-loading of CO_2 from hemoglobin (Haldane effect, Video 2, Slide 10). Note also that the diffusion of CO_2 from pulmonary capillary blood to alveolar air favors the reaction of bicarbonate ion to form CO_2, which diffuses from RBCs to alveolar air – see Video 2, Slide 4.

3. [20 points] Describe/discuss/explain the effect(s) of increased temperature and of increased acidity on the oxygen - hemoglobin saturation curve. Describe/ discuss/explain the physiologic significance of such effect(s).

Increased temperature and/or acidity (increased $[H^+]$; lower pH) shift the hemoglobin – oxygen saturation curve to the right (Video 2, Slides 8, 9). This means that, at a given P_{O2}, hemoglobin will bind less oxygen (WRT the un-shifted curve). The physiological significance is that, since the temperature and acidity of metabolizing tissue are both elevated, more oxygen is delivered to metabolizing tissue (right-shifted curve; increased temperature and acidity), where it is needed, then might otherwise be delivered had the curve not been right-shifted.

Rev 0, 4/7/17 - adapted from Spring 2016
Rev 1, 11/23/17 - update refs to include B&L[7]
Rev 2, 8/3/18 - update to 601; minor text changes so that question text matches Assignment. Minor clarifications to responses.