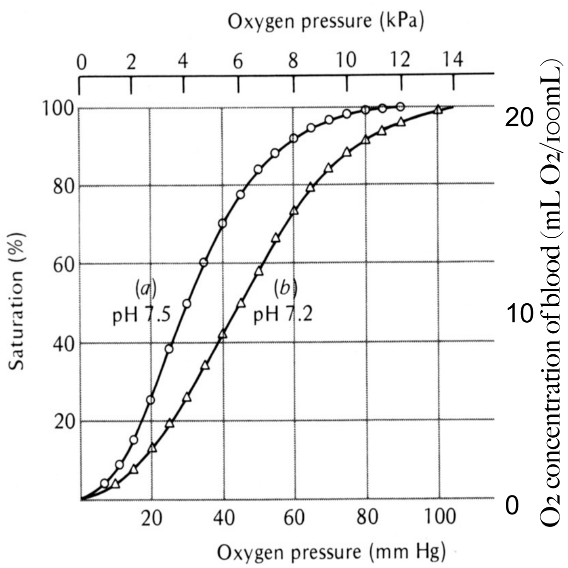
Discussion Week10

Animal Physiology
Discussion Questions and Reading Assignments

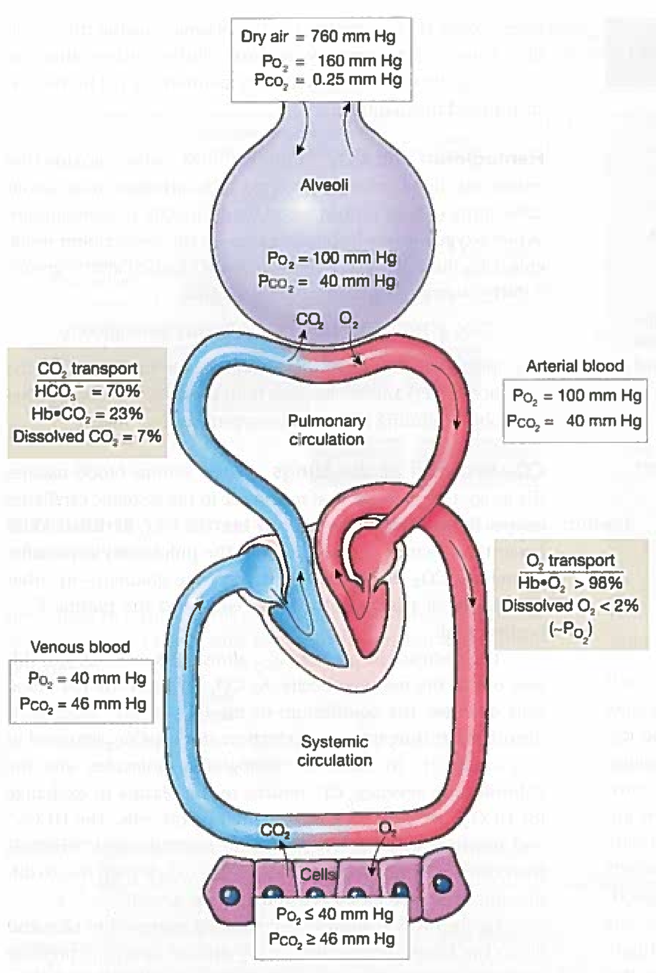
Read: Oxygen binding properties Withers pp 740-2, paying attention to the Oxygen dissociation curve, why it is sigmoidal, and the Bohr and Root effects. Take a look at Table 15-4, and supplement 15-1 which explains the O2 equilibrium curve. Understand: the properties of hemoglobin with regards to O2 affinity (binding) at different pO2, in different parts of the body, why it changes, and how the affinity is manipulated to deliver O2 to the right places in the right situations.

Hemoglobin and Oxygen Delivery



1. Assume curve (a) represents the pO2 of blood at rest. Draw a vertical line to show the pO2 of arterial blood. Draw another vertical line to show pO2 of systemic circulation at the tissues. How much O2 is delivered because of lower pO2? Quantify that difference. Now do the same for the Bohr effect, assuming the shift at curve as a result of increase pCO2 is shown by curve (b.) What has changed and why?

2. How low does the pO2 of tissues get during exercise (see slide)? How much O2 is delivered at tissues?



3. Overbreathing or hyperventilation in the sick causes hypocapnia or reduced CO2 tension, which can cause a reverse Bohr effect. They more they breathe at rest, the lower CO2 tension and increased O2 affinity for Hb at the tissues. From what you know, what physiological mechanisms could explain this? How much less O2 is delivered if we assume a similar left-ward Bohr shift?

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Reading assignment: Withers Aquatic respiration: skim 565-72, read 573-4, 585-99, supplement 12-2. ALTERNATIVELY, read HWA chapter 22 + HWA 586-587 (countercurr) + HWA 590-594 (fish).

Gas Exchange in Air vs Water and Aquatic Respiration

Know:

- [ ] the O_2 and CO_2 composition of air and water
- [ ] Relative Humidity, PV=nRT, and Standard Temp and Pressure
- [ ] Dalton's Law and partial pressures of gasses
- [ ] Henry's law describing the molar concentration of a gas in water
- [ ] Diffusion (Fick's Law) vs. Bulk Flow
- [ ] Concurrent vs. counter-current flow
- [ ] The structure of vertebrate gills

Discuss:

1. Compare and contrast the properties of air vs. water as respiratory media. What would these differences mean to a respiring animal? Breathing in water is expensive! (Why)? How have fishes reduced the energy cost of breathing?

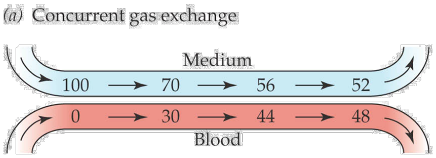
2. Standard atmospheric pressure at sea level is 101 kPa, and is composed mainly of O_2, CO_2, and N_2 (percents: 20.9, .03, and 78%; partial pressures: 21.1, .03, and 79.8kPa). What is the molar fraction of each gas? Now consider the gas composition in different environments. What happens to % composition and molar fraction with increased altitude or depth underwater? What happens when the air is not dry but has some water vapor in it? (feel free to solve in class with your group but be prepared).

3. What is diffusion vs. bulk flow (convection)? Where does each occur in the circulatory system? Write out Fick's law. What does each parameter mean? Which parameters can change in order to evolve more efficient respiratory systems? Which parameters can be changed within an individual? Now consider bulk flow. How can O_2 delivery be increased?

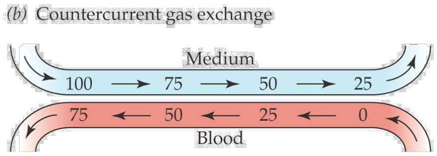
4. The gills of fishes are remarkable structures illustrating evolutionary adaptations for increasing O2 extraction. Describe the morphology of filamentous gills and explain the many features which maximizes surface area. Look back at question 3. Besides surface area, how else do fix maximize O2 extraction? Make sure you also consider flow patterns of water vs. blood?

5. Describe Concurrent vs. Countercurrent flow in respiratory systems. How does each impact the concentration gradient of O2 between the media (i.e. air or water) and the capillaries? Which is more efficient? Calculate Efficiency for these situations, and draw a graph of Distance along the gas exchange surface vs. pO2 :

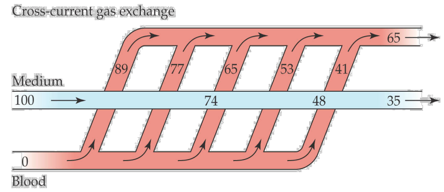
(a) Concurrent gas exchange



(b) Countercurrent gas exchange



Cross-current gas exchange



Reading assignment: Withers pp. 609-631 OR HWA chapter 23 + Withers 626-632, skip invertebrates

Aerial Respiration

Know:

- [ ] Air flow patterns of vertebrates
- [ ] Lung Volume (V_L or V_T), tidal volume (V_t), Dead space volume (V_D), Alveolar ventilation volume (V_A or V_a), Alveolar Minute Volume (V_{AE}), and Breath Rate (BR).

Discuss:

1. What is dead space? Why does it occur? What is the difference between anatomical and physiological dead space?

2. Compare the pumps of amphibians, reptiles, mammals, and birds. Which operate by positive pressure? Negative pressure? Is it inspiration or expiration or both that are active? Which morphological features are involved in pumping air in or out?

3. Describe the ventilation of tidal lungs vs. bird lungs in terms of air flow patterns. Where are the gas exchange surfaces? Which has more surface area devoted to gas exchange? Which is more efficient? Why? Birds have unidirectional flow but still have tidal volume. Explain.

4. If the lungs are essentially one cell thick in many places to increase diffusion, why don't they collapse? Why would lung collapse be a problem? How are they protected structurally, morphologically, or physiologically from collapsing?

5. What is DLO_2? Where does it come from? How does pulmonary diffusing capacity balance morphological capacity for oxygen delivery with physiological needs?

6. Practice Problem for Respiration: A 70 kg Human at rest has RMR ~ 333 kJ/hr, human total lung volume (L_V or sometimes V_T) ~ 4,000 ml

Tidal volume at rest (amt that goes in and out in a breath) ~ 15% lung volume = ________

Dead space ~ 3.75% of lung volume = ____________

V_A = alveolar ventilation volume = _______________ (what is this?)

Pressure of oxygen that goes in = pO2inspired = partial pressure of O_2 in air = 21 kPa
Tidal – not all air that goes in makes it into the lung; therefore, not all becomes mixed
* pAO_2 air = 13.8 kPa for most tidal lungs
what is the equation for pO2expired?

pO2expired = ____

VO_2 (rate of oxygen consumption: How much O_2 for RMR?; remember 20 kJ/LO_2) =

Convert VO_2 (rate of oxygen consumption) to ml/min =____________ (1 hr/60 min) (1000 mL/L) = _________ ml/min (O_2)

To get breath rate of human at rest, (1) solve for minute ventilation (V_E) and then (2) solve for Breath rate from $V_E = V_t * BR$:

$VO_2 = (V_E\,(pO2_{inspired} - pO2_{expired})) / P_{barometric}$

V_E =

Convert V_E to ml air/min:

____________ (1 hr/60 min) (1000 mL/L) = _________ ml/min (Air)

Breath rate = V_E / V_t = __________________ breaths per minute for a human at rest

Check: Does this match predicted vales of VO_2 (oxygen flux) from measured values of DL_{O2} (0.3 ml/[min kPa kg] for human at rest), and $pAO_2 - pcO_2$ (2.7kPa for most vertebrates)? Withers page 629.