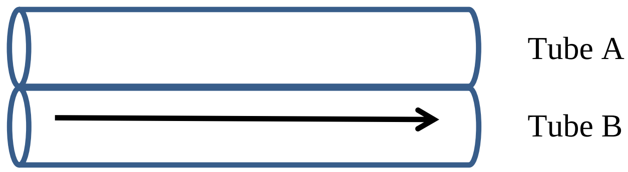
Gas Exchange

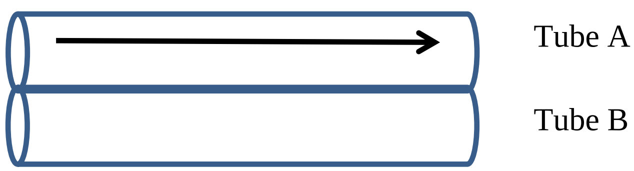
A. Influence of concentration gradient on gas diffusion rate

1. You have two tubes of permeable membrane.

a. Add an arrow to illustrate **concurrent fluid flow** in Tubes A and B.



b. Add an arrow to illustrate **countercurrent fluid flow** in Tubes A and B.



c. Describe the movement of oxygen between Tube A and Tube B if the oxygen concentration in Tube A and B are the same.

d. Describe the movement of O_2 between Tube A and Tube B in example (a) above if the O_2 concentration in the fluid entering the ***left end*** of ***Tube A*** is 120 ppm and the O_2 concentration in the fluid entering the ***left end*** of ***Tube B*** is 80 ppm. What will the concentrations look like at the right end of each tube?

e. Describe the movement of O_2 between Tube A and Tube B in example (b) above if the O_2 concentration in the fluid entering the ***left end*** of **Tube A** is 120 ppm and the concentration of O_2 in the fluid entering the ***right end*** of ***Tube B*** is 80 ppm. What will the concentrations look like at the opposite end of each tube? Will the concentration of oxygen reach equilibrium at either end of the tubes?

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2. Let's now consider a biological example. We'll look at a fish.

Countercurrent Exchange in Fish Gills by Craig Savage
http://www.youtube.com/watch?v=cVFqME-NW9s

a. Explain why **con**current flow is not as efficient as **counter**current flow for gas exchange.

b. Water flows in one direction over the gills of fish. Air flows both in and out of terrestrial vertebrate lungs. How does one-way flow in fish gills provide for more efficient gas exchange?

B. Influence of Structure on Gas Diffusion Rate

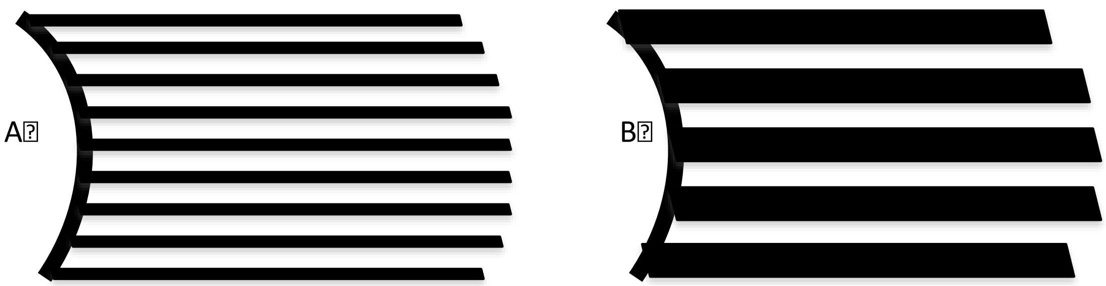
3. Describe or sketch the gill. How is the structure of the gill adapted as a respiratory surface?

4. Predict how the gill structure of a fast-moving fish like a tuna or great white shark might differ from that of a slow moving, sit-and-wait predator like a grouper.

Fick's Law of Diffusion:

$$Q_s = DA\left(\frac{C_2 - C_1}{x}\right)t$$

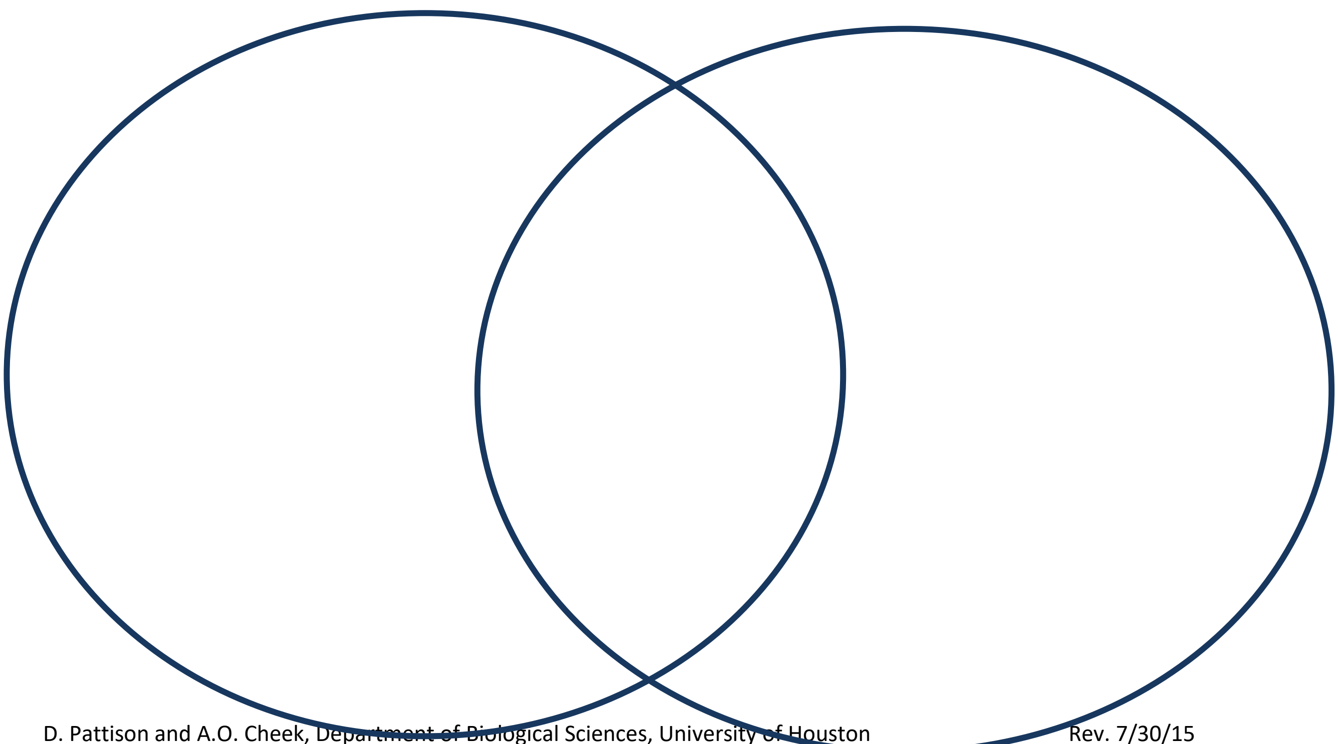
5. Examine the diagrams of gill lamellae shown below. Which type of structure would <u>reduce</u> gas diffusion rate? List 2 reasons and indicate how each is related to a term in Fick's Law of Diffusion.



C. Respiratory systems in Terrestrial Animals

6. Add information to the Venn diagram below to compare the respiratory systems of insects and mammals. How are they similar? How are they different?

INSECTS **MAMMALS**



Teaching Tips for Peer Mentors

Explain to students that the goal of this recitation is to understand the physical factors affecting gas exchange across respiratory membranes, especially the roles of concentration gradient and structure of the respiratory organ. If the lecture instructor has already covered cellular respiration, start class with some leading questions:

a. What is the point of cellular respiration? *To make ATP to power biological processes*

b. What happens to the electrons in cellular respiration? Where do they go? Oxygen

c. What is a fancy name for oxygen when discussing cellular respiration? A terminal electron acceptor

d. So why do humans and other terrestrial animals breathe? So we have oxygen to serve as a terminal electron acceptor which drives the electron transport chain and ultimately production of ATP.

Question 1: Have students answer questions 1a-1e in groups. Stop and go over the answers on the board. Have <u>students</u> come to the board and add the arrows and oxygen concentrations. Call on teams to respond. The answer to 1c should be 0. This question is not a trick, but is deliberately asking them to apply their knowledge of how concentration gradient influences diffusion.

Show the video on fish gills.

Question 2: Have students answer question 2a – 2b. 2a: Ask several students to share their answer. Make sure they understand that countercurrent flow allows a concentration gradient to persist along the entire length of the respiratory surface, but concurrent flow allows equilibrium to develop quickly. 2b: Some questions to ask students as they work on their answers: Think of the mechanics of moving air versus water. Which is easier to move? Would reversing the direction of water flow be more, less, or equally difficult as reversing the direction of air flow? Think about oxygen solubility in water vs in air. Which medium can hold more oxygen?

Question 3: The descriptive answer should include the thinness of the respiratory membrane and the value of the many lamellae in increasing surface area (similar to alveoli in mammals).

Question 4: Ask students to think about the characteristics of respiratory surfaces that enhance gas exchange, then ask how these characteristics might be different in a fish with high oxygen demand (the fast mover) and a fish with low oxygen demand (the slow mover). Student answers should include factors that would increase surface area - more or longer lamellae or and more capillaries in gills.

Question 5: This question asks students to apply their conceptual understanding of the factors affecting diffusion rate to a specific scenario. Make sure students are able to identity which terms in Fick's Law of diffusion would be different for Structure A and Structure B. Fewer lamellae reduces surface area (A), thicker lamellae increase membrane thickness (x)

Question 6: Have students list characteristics of the 2 respiratory systems and figure out which are shared and which are unique to each group of animals.

Similarities: Both move air, are branching systems of air tubes, respiratory surface is thin to facilitate diffusion

Differences: Insects: spiracles and a tracheal system; O2 diffuses directly into the tissues; Circulatory system is not involved. Mammals: lungs, O2 diffuses into the blood which carries it to the tissues

Notes to Faculty

Video link: The introductory video link is "Countercurrent Gas Exchange in Fish Gills" by Craig Savage. The link was functional when accessed on 7/30/2015. https://www.youtube.com/watch?v=cVFqME-NW9s

Fick's Law of Diffusion:

$$Q_s = DA\left(\frac{C_2 - C_1}{x}\right)$$

Qs = quantity of substance crossing the membrane
D = membrane-specific diffusion constant
A = surface area
C2-C1 = concentration (or pressure) gradient across the membrane)
x = membrane thickness
t = time

This algebraic version of Fick's Law of Diffusion is used in this activity and was presented in lecture to explain physical factors that influence diffusion across membranes. These factors were explicitly discussed in lectures on absorption across the digestive epithelium and gas exchange across the gill and alveolar epithelia of fish and air-breathing vertebrates.