

# Solution to Problems in Chapter 1, Section 1.10

1.1. The relative importance of convection and diffusion is evaluated by Péclet number,

$$Pe = \frac{UL}{D_c} \quad (S1.1.1)$$

(a) Solving for  $L$ ,  $L = PeD_c/U$ . Assume that convection is the same as diffusion, i.e.,  $Pe = 1$ .  $L$  is 0.123 cm.

(b) The distance between capillaries is  $10^4$  cm; oxygen needs to travel half of this distance, which yields a value of  $Pe$  equal to 0.0055. Therefore, convection is negligible compared with diffusion.

1.2. Since  $R_{O_2} = R_{CO_2}$ , equation (1.8.4) is simplified to the following:

$$C_{O_2} + R_{O_2}P_{O_2} = C_{CO_2} + R_{CO_2}P_{CO_2} \quad (S1.2.1)$$

$P_{O_2}$  and  $P_{CO_2}$  are 10 mmHg and 40 mmHg for arterial blood and 30 mmHg, 70 mmHg for venous blood.  $C_{O_2}$  is 0.0203 and  $C_{CO_2}$  is 0.45 + 0.0001 M for men, and 0.0203 and  $C_{CO_2}$  is 0.40 + 0.0001 M for women. Based on these data, the fraction of oxygen in plasma and bound to hemoglobin is 1.5% and 98.5% in arterial blood, and 0.03% and 99.97% in venous blood for men. Corresponding values for women are 1.7% and 98.3% in arterial blood, and 0.03% and 99.97% in venous blood. Most oxygen in blood is bound to hemoglobin.

1.3. For  $CO_2$ , 70% is moved in plasma and 30% is in red blood cell. Therefore, the total change of  $CO_2$  is  $2.270(70) + 1.060(30) = 2.10 \text{ cm}^3 \text{ per } 100 \text{ cm}^3$ . For  $O_2$ ,  $P_{O_2}$  changes from 30 to 100 mmHg after blood passes through lung artery. Using data in problem (1.2), the total  $O_2$  concentration in blood is 0.0003 M in arterial blood and 0.0003 M in venous blood. At standard temperature (273.15 K) and pressure (1 atm = 101,325 Pa), 1 mole of gas occupies 22,400 cm<sup>3</sup>. Thus, the  $O_2$  concentration difference of 0.0003 M corresponds to  $5.28 \text{ cm}^3 \text{ } O_2 \text{ per } 100 \text{ cm}^3$ . While larger than the difference for  $CO_2$ , the pressure difference driving transport is much larger for  $O_2$  than  $CO_2$ .

1.4. The diffusion time is  $L^2/D_c = (10^4 \text{ cm})^2/(2 \times 10^7 \text{ cm}^2/\text{s}) = 0.0005 \text{ s}$ . Therefore, diffusion is much faster than reaction and does not delay the oxygenation process.

1.5.  $V = \pi R^2 L$ , and the  $S = 2\pi RL$ , where  $R$  is the vessel radius and  $L$  is the length.

Order	volume, cm <sup>3</sup>	surface area, cm <sup>2</sup>	cumulative volume, cm <sup>3</sup>	cumulative surface area, cm <sup>2</sup>
1	0.00158	26.27	0.00158	26.27
2	0.00365	37.32	0.00523	63.59
3	0.00739	51.44	0.01262	95.03
4	0.01199	66.23	0.02461	123.27
5	0.01768	81.44	0.04229	149.86
6	0.02447	97.76	0.06676	173.14
7	0.03235	115.96	0.09911	198.79
8	0.04132	135.83	0.14043	218.73
9	0.05149	157.17	0.19192	237.69
10	0.06286	179.79	0.25478	255.69
11	0.07543	203.59	0.33021	272.59

# Solutions Manual For Transport Phenomena In Biological

**James P. Welty**



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