Chapter 7
Mass Transport and Heat Transfer in the Microcirculation

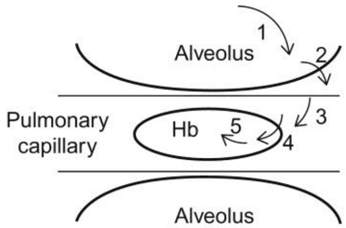


Figure 7.1 The five salient diffusion events for red blood cells within the pulmonary capillaries to become oxygenated. By comparing the relative rates of diffusion of these five events, we can see that respiratory boundary diffusion, blood diffusion, and diffusion/association with hemoglobin are the rate-limiting steps of red blood cell oxygenation. Models of red blood cell oxygenation would assume a homogenous distribution of air within the alveolus and a rapid diffusion across the red blood cell membrane.

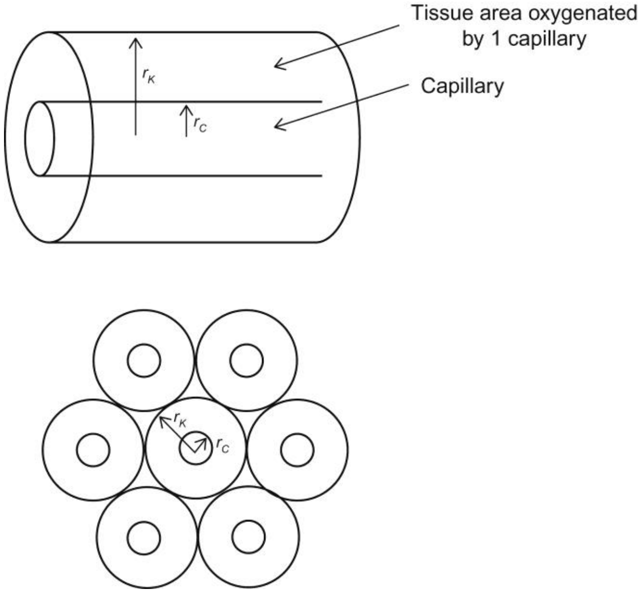


Figure 7.2 Krogh model for tissue oxygenation around uniformly spaced capillaries. r_K is the Krogh radius and r_C is the capillary radius. This model assumes that each capillary can supply a uniform area of tissue with oxygen and is very accurate for predicting the oxygenation of tissue with ordered arrays of capillaries (like muscle). However, this model does not take into account the decrease in oxygen along the capillary length, inhomogeneities within the tissue, and nonordered arrays of capillaries (as seen in brain tissue). Even accounting for these limitations, the Krogh model can calculate an accurate estimate of tissue oxygenation.

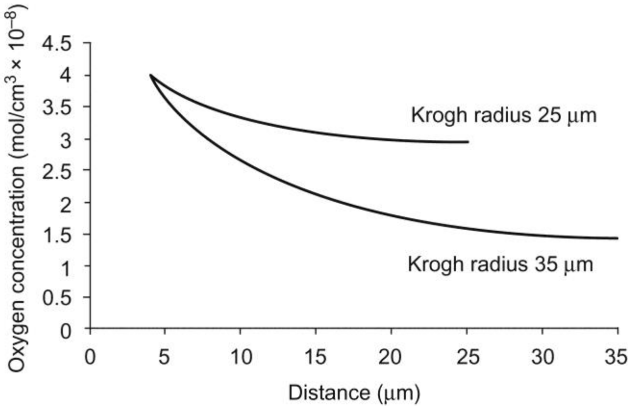


Figure 7.3 Oxygen concentration as a function of distance and the Krogh radius.

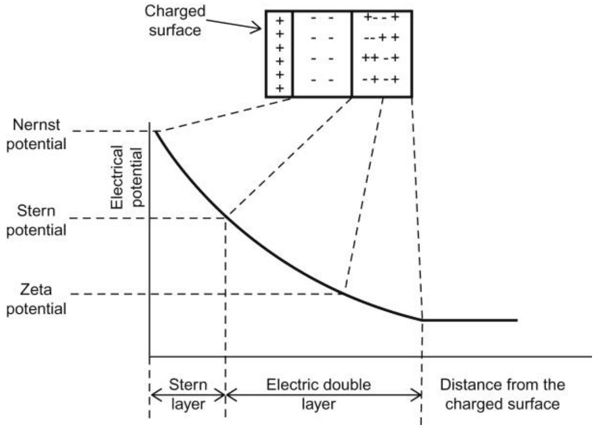
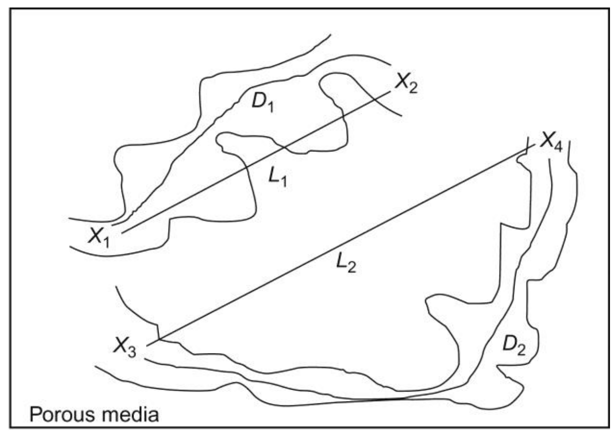


Figure 7.4 Electrostatic forces near a charged surface, which tend to organize water (or other ions) close to the boundary. The layer that is closest to the charged boundary and has the highest organization is termed the Stern layer. A second layer, of mostly organized charged species, is termed the electric double layer. Beyond the electric double layer, the charged species would resemble the bulk properties.



$$T_{X_1 \rightarrow X_2} = \frac{D_1}{L_1}, \mathrm{T}_{X_3 \rightarrow X_4} = \frac{D_2}{L_2}$$

Figure 7.5 Tortuosity is defined as the actual minimum distance between two points connected by a pore divided by the straight line path between the points. This value can only be greater than or equal to 1.

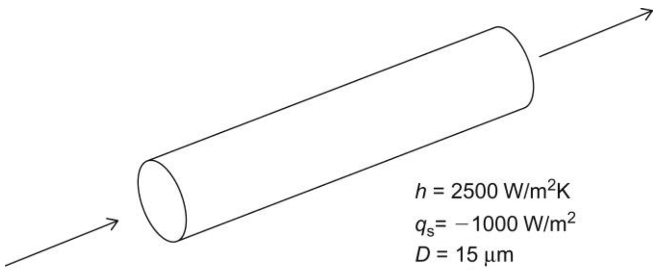


Figure 7.6 Heat transfer through a capillary.

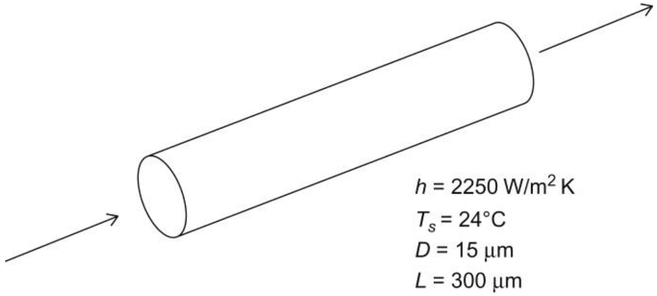


Figure 7.7 Heat transfer through a capillary.

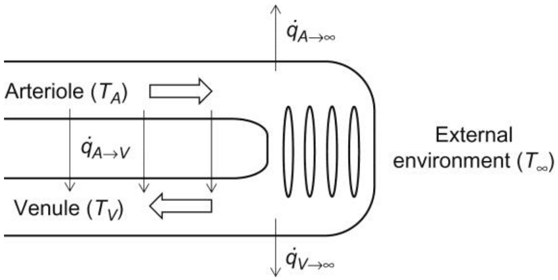


Figure 7.8 Representation of an arteriole–venule pair as a counter-current heat exchanger. There are at least three heat transfer events that occur within each arteriole–venule pair; heat transfer from the artery to the external environment, heat transfer from the vein to the external environment, and heat transfer from the artery to vein. Mathematically, this can be represented using convection methods, as outlined in the text.