

EFB 462 Animal Physiology: Environmental & Ecological
Fick's Law

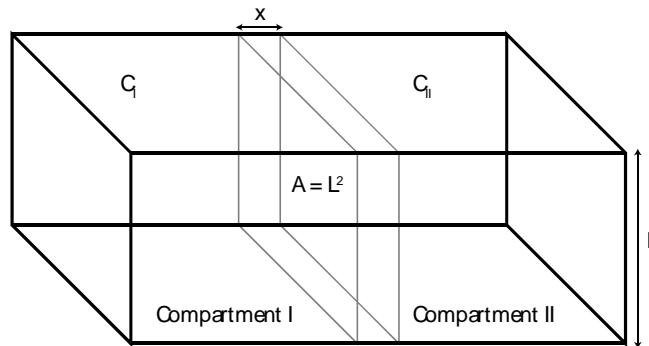
Diffusion is the fundamental process driving the movement of materials throughout the body. Diffusion may be supplemented by active transport or convection, but ultimately, diffusion delivers the goods.

Diffusion is governed by Fick's law (not to be confused with the Fick principle, which is concerned with the integration of convection and diffusion gas exchange, and which is the subject of another essay). The general form of Fick's law is as a differential equation:

$$M_x = -D_x \cdot \frac{dC}{dx}$$

Where M_x is the flux rate of a diffusing substance X, D_x is the diffusion coefficient for X in the diffusion medium, such as air or water, C is concentration and x is the thickness of a diffusion barrier. Usually, the flux rate is expressed as a *mass flux rate* (with units of kg s^{-1}), but it can also be expressed as a molar flux rate (mol s^{-1}). Concentration can also be expressed in various ways (see below). Depending upon how these are expressed will determine the units of both the flux rate and the diffusion coefficient.

Solving the differential form of Fick's law depends upon the geometric context of the flux. Most simply, Fick's Law is expressed as the *one-dimensional* form, in which flux proceeds along a single dimension of length. Imagine a box divided into two compartments, I and II, separated by a diffusion barrier of thickness x :



The differential form of Fick's law can be solved to express the diffusion rate of material across the boundary:

$$M_x = \frac{-AD}{x}(C_I - C_{II})$$

In this equation, the quantity $\frac{-AD}{x}$ is called the *shape factor*, and is unique to the particular situation of diffusion in one dimension across a flat plate of thickness x . The shape factor is an important design principle in diffusion-based systems. For example, adjusting the shape factor can considerably alter the rate of diffusion even when the concentration difference ($C_I - C_{II}$) does not change. Increases of area, A , or reductions of barrier thickness, x can both increase diffusion rate independently of the concentration difference.