Selected Notes from Chapter 2, Heinsohn and Cimbala

The respiratory system:

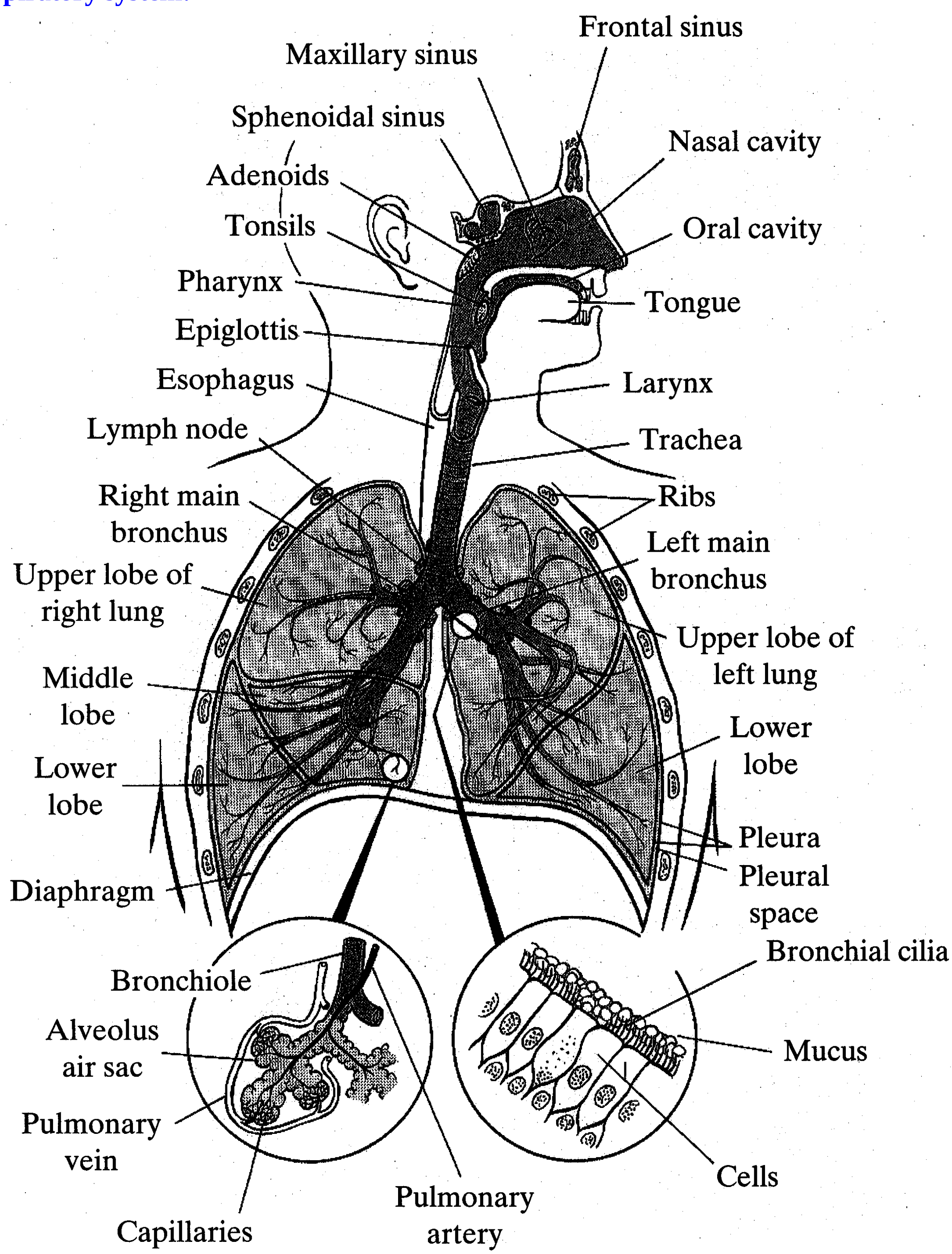


Figure 2.1 Components of the respiratory system (courtesy of the American Lung Association).

Branching airways:

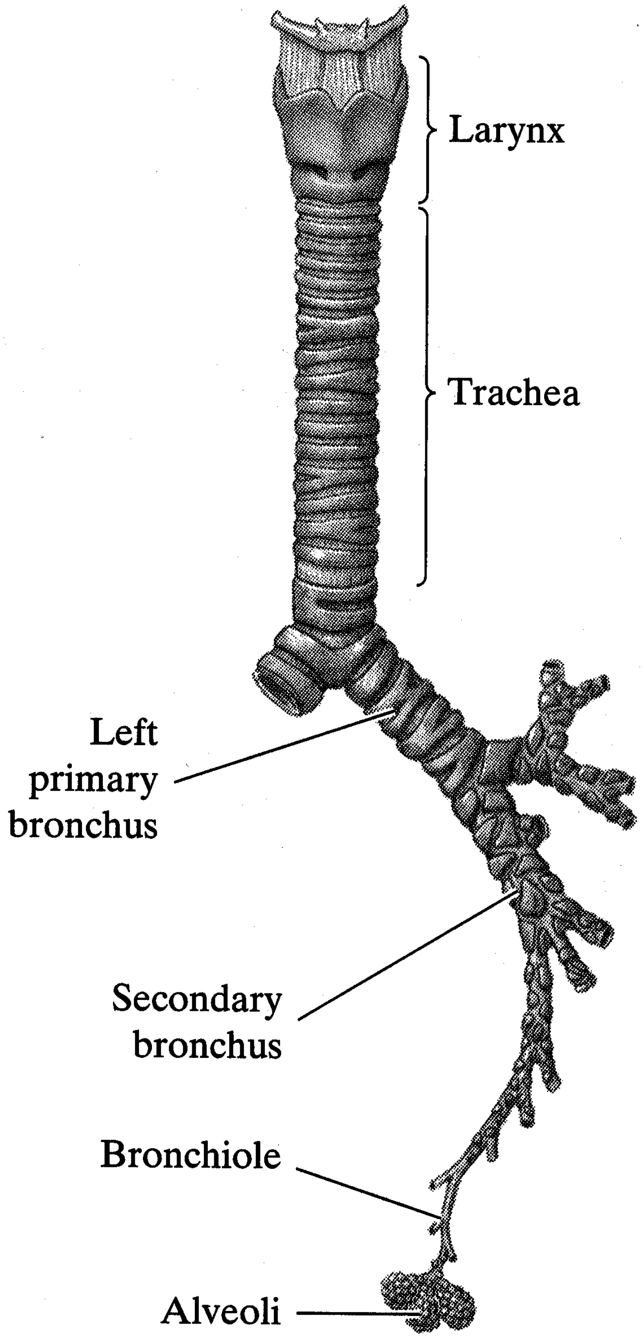


Figure 2.2 Schematic diagram of branching airways. The trachea divides into two primary bronchi, one to each lung. Each bronchus divides at least 20 times, and finally terminates in a cluster of alveoli (from Heinsohn & Kabel, 1999).

Cilia:

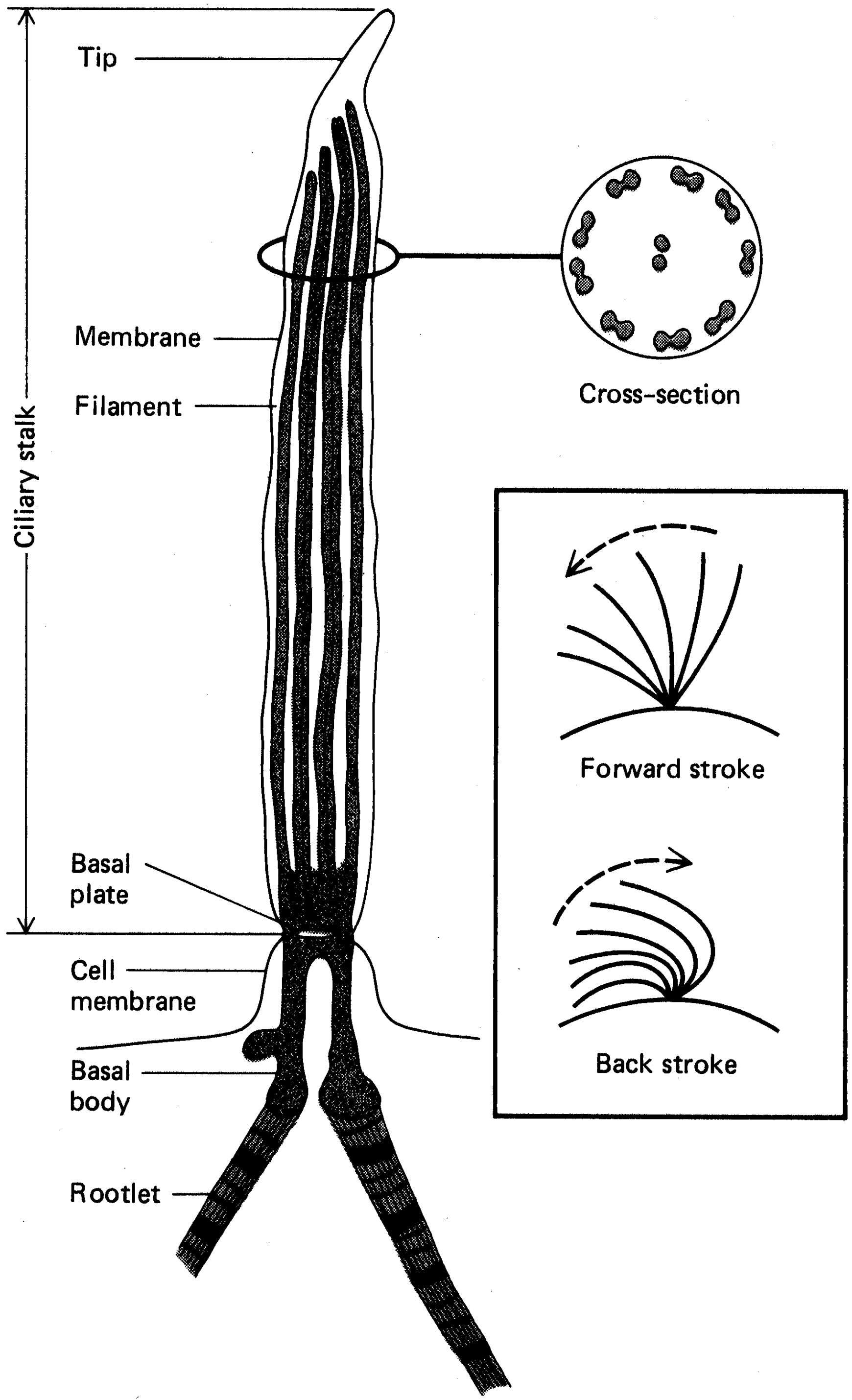


Figure 2.3 Structure and function of the cilium (adapted from Guyton, 1986).

Cilia (close-up view in the bronchial tubes):

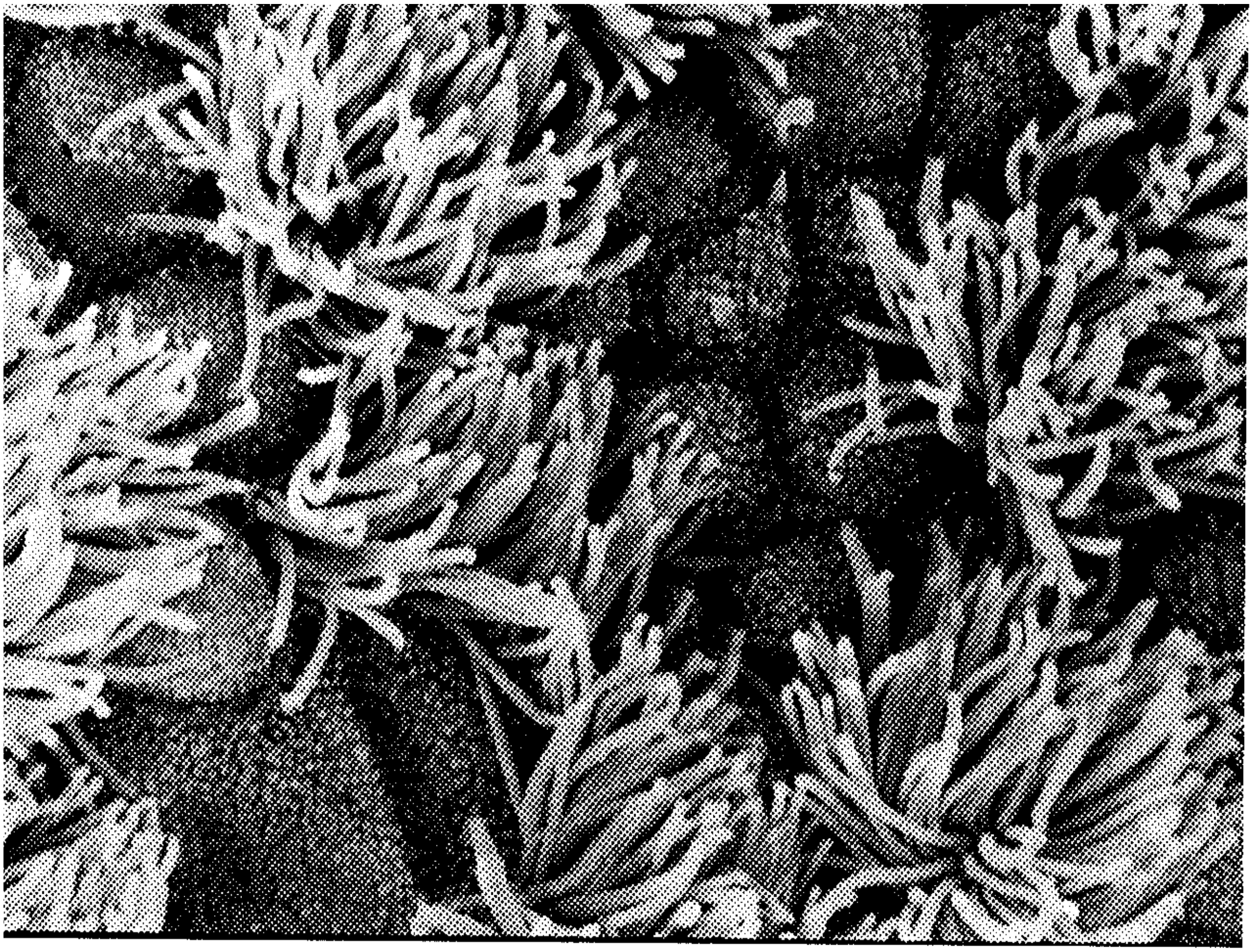


Figure 2.4 Scanning electron micrograph of a portion of a bronchial passage showing cilia interspersed with mucus-secreting cells whose surfaces are covered with microcilli (from Heinsohn & Kabel, 1999).

Alveoli:

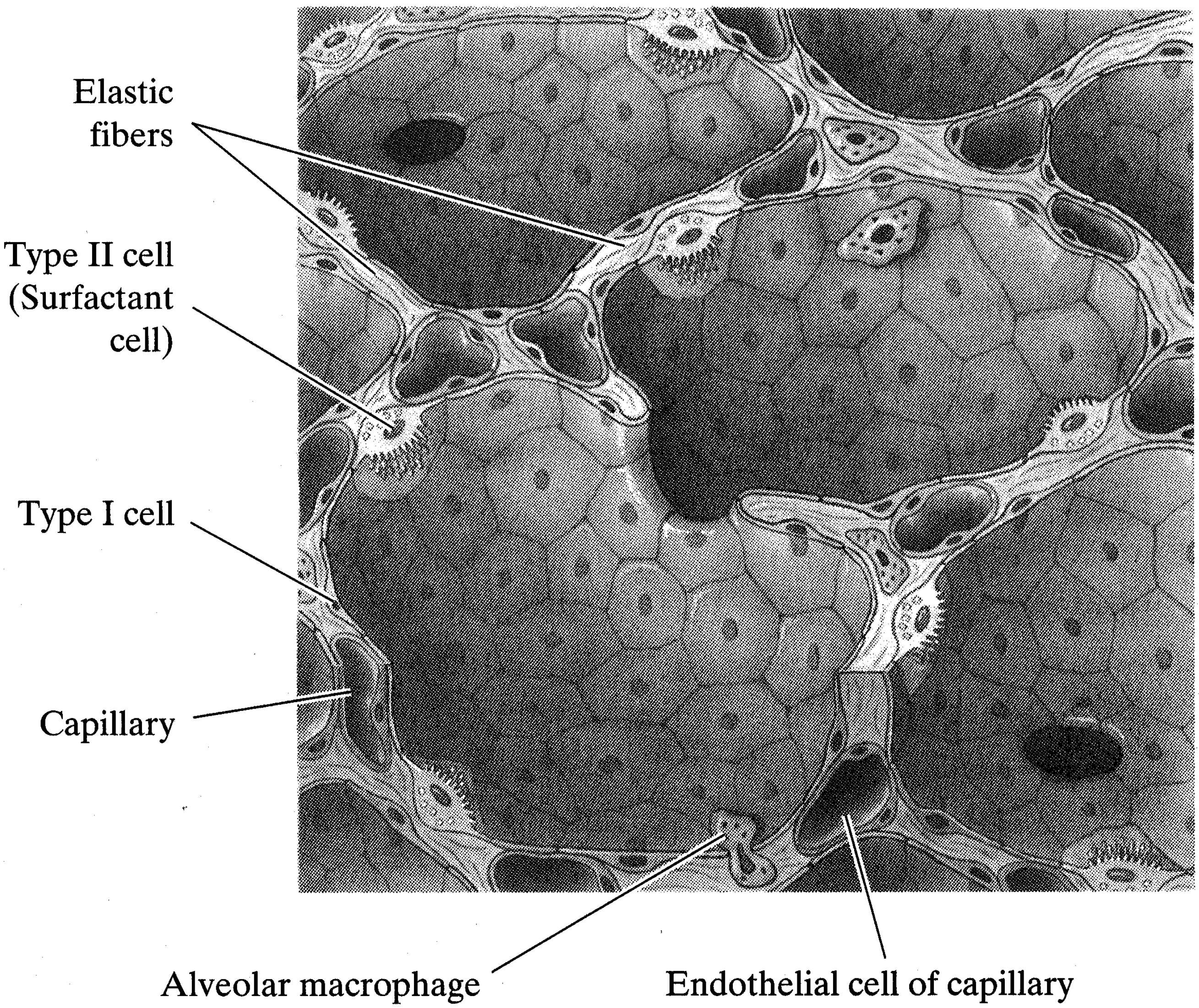


Figure 2.5 Alveoli in the pulmonary system; the alveoli are composed of type I cells for gas exchange and type II cells that synthesize surfactant; macrophage lying on the alveolar membrane ingest foreign material that reach the alveoli (from Heinsohn & Kabel, 1999).

The Weibel model of the lung:

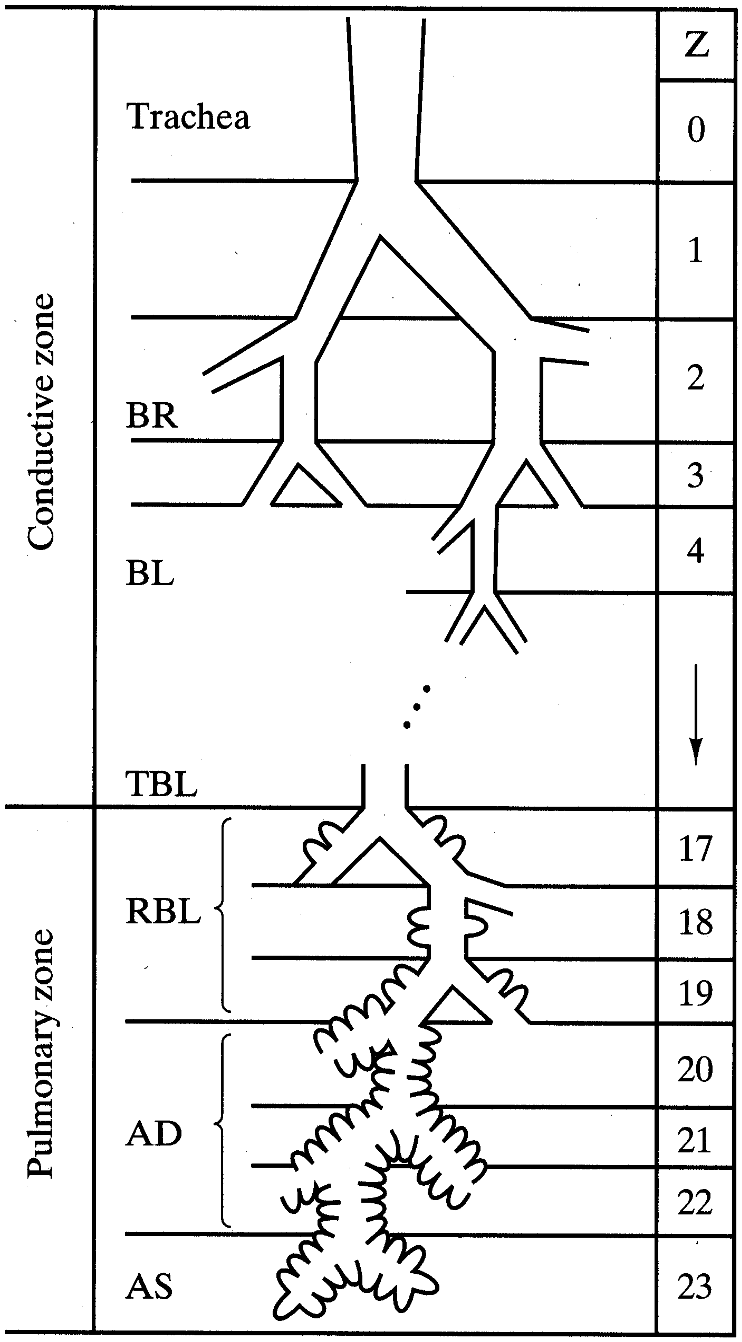


Figure 2.6 Systematic Weibel model; airway generation (Z), bronchi (BR), bronchioles (BL), terminal bronchiole (TBL), partially alveoliated respiratory bronchioles (RBL), fully alveoliated ducts (AD), and terminal alveolar sacs (AS) (redrawn from Ultman, 1985).

Spirometry:

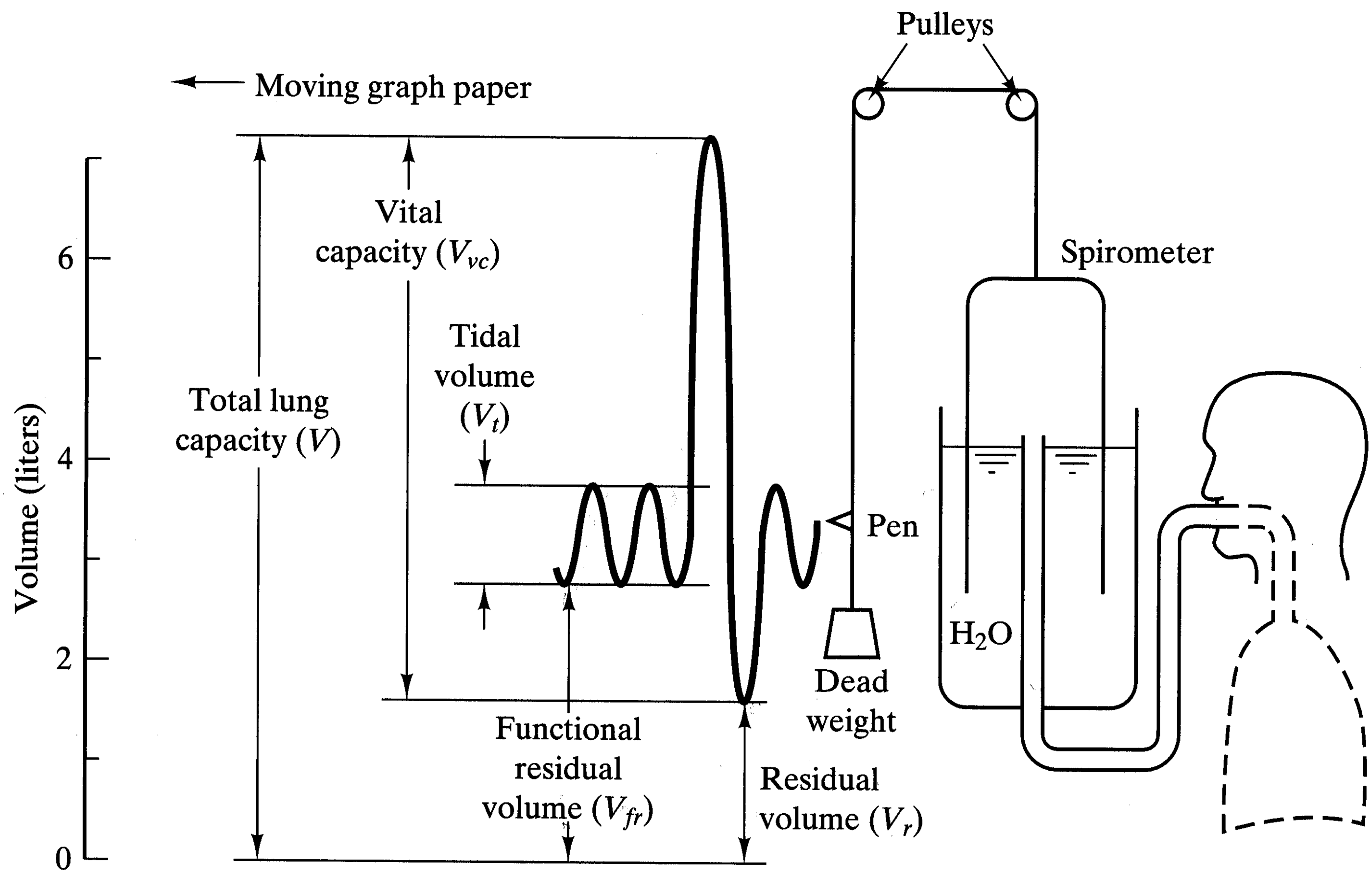


Figure 2.11 Lung volumes and elements of spirometry. A pen records changes in the air volume on graph paper that moves to the left. The residual volume and functional residual volume cannot be measured with the spirometer (from Heinsohn & Kabel, 1999).

Table 2.4 Ventilation, blood flow, and the ventilation perfusion ratio (R_{vp}) during various activity levels (abstracted from Ultman, 1988 and 1989).

parameter	**exercise or activity level**			
	rest	**light**	**moderate**	**heavy**
ventilation rate, Q_t (L/min)	11.6	32.2	50.0	80.4
frequency, min^{-1}	13.6	23.3	27.7	41.1
tidal volume, V_t (L)	0.85	1.38	1.81	1.96
V_d/V_t	0.34	0.20	0.16	0.16
blood flow, Q_b (L/min)	6.5	13.8	18.4	21.7
$Q_a = Q_t(1 - V_d/V_t)$ (L/min)	7.66	25.8	42.0	67.5
$R_{vp} = Q_a/Q_b$	1.18	1.87	2.28	3.11

The extended Bohr model:

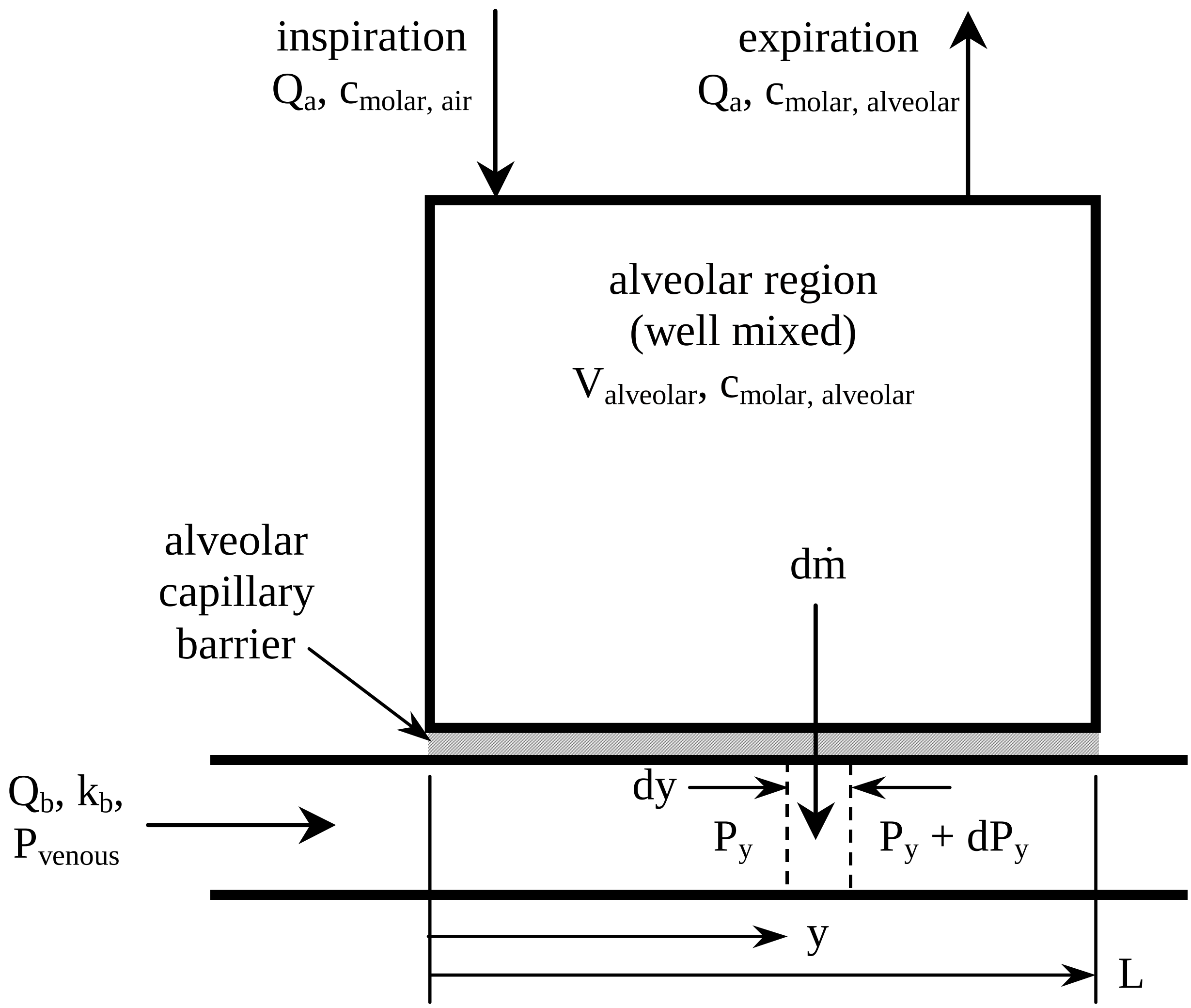


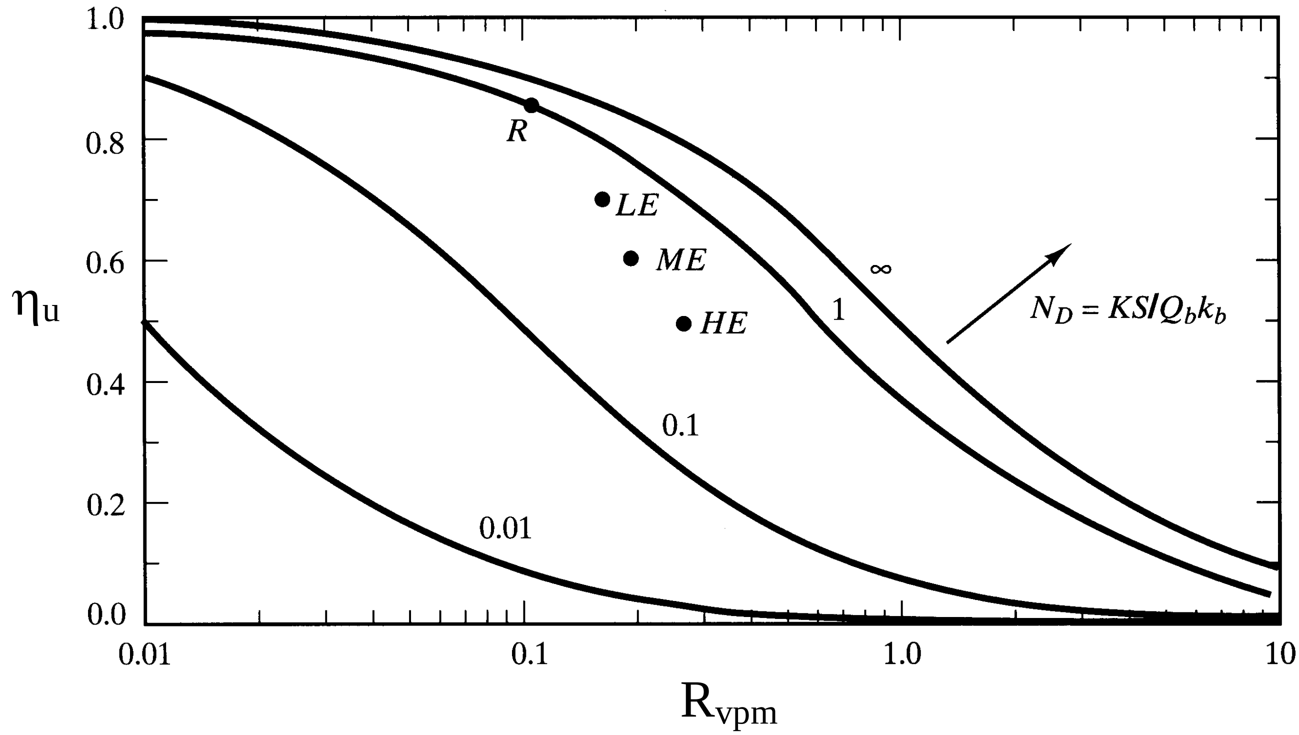
Figure 2.24 Extended Bohr model illustrating mass transfer of a nonreacting gas through the alveolar capillary barrier.

See algebra in the book. We treat the alveolar volume as a control volume for the air and gases, and we treat the vein as a control volume for the blood and absorbed gases. The following equation results:

Uptake absorption efficiency

$$\eta_u = \frac{1}{1+\dfrac{R_{\text{vpm}}}{1-\exp\left(-N_D\right)}} \qquad (2\text{-}37)$$

where N_D is the ***diffusion parameter***, $N_D = K\,S/(Q_b k_b)$, K is the ***overall mass transfer coefficient***, S is the ***total useful working surface area of the alveoli***, Q_b is the ***blood flow rate***, and k_b is the ***solubility coefficient***.



activity level	N_D	R_{vpm}	η_u (%)
rest state (R)	1.0	0.11	85.
light exercise state (LE)	0.49	0.18	69.
moderate exercise state (ME)	0.37	0.21	59.
heavy exercise state (HE)	0.31	0.29	48.

Figure 2.26 Absorption efficiency versus modified ventilation-perfusion ratio for different values of the diffusion parameter corresponding to rest (R), light exercise (LE), moderate exercise (ME) and heavy exercise (HE) (adapted from Ultman, 1988).

Carbon Monoxide:

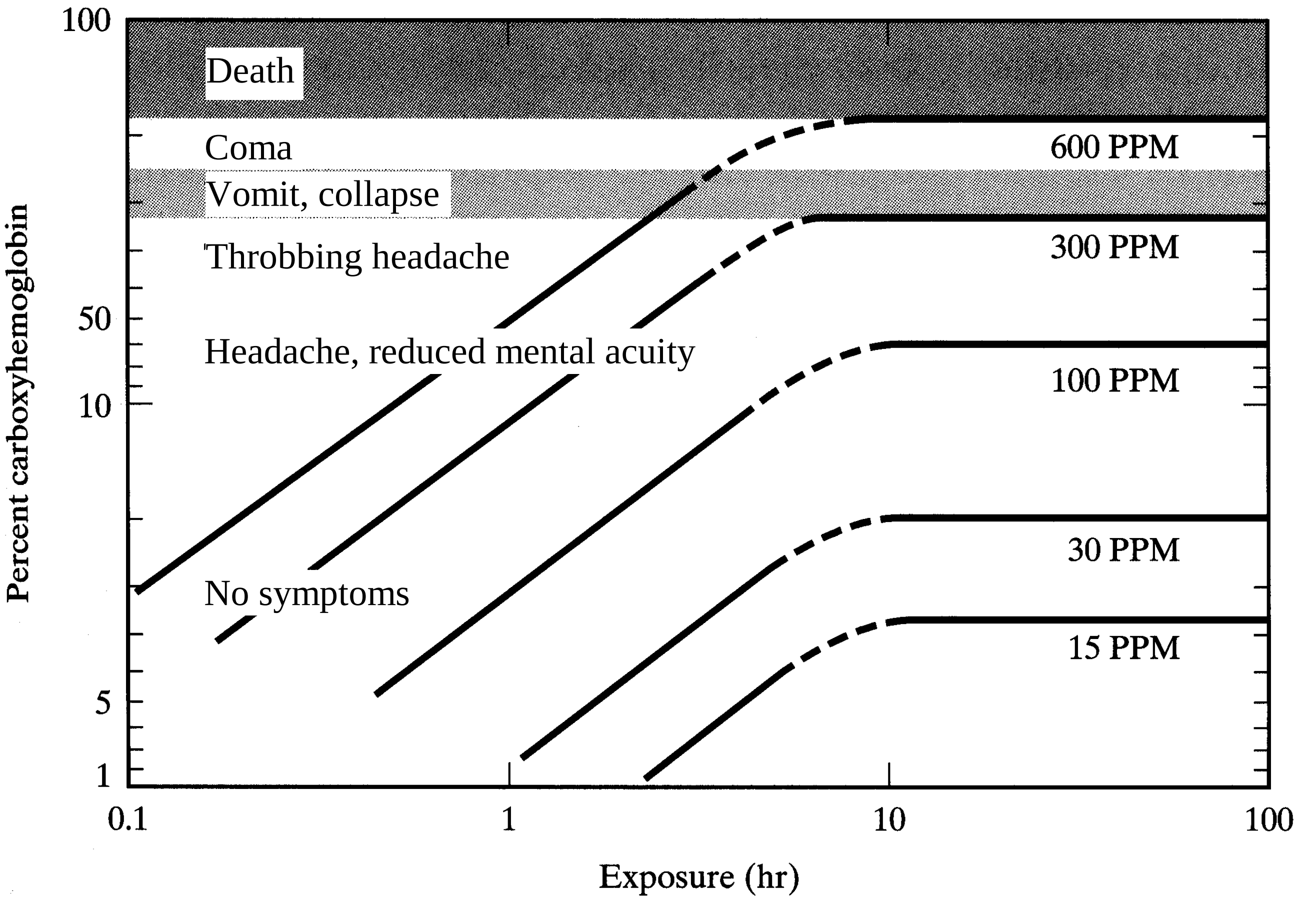


Figure 2.41 Response to carbon monoxide as a function of concentration (PPM) and exposure time (hr). The OSHA 8-hr PEL is 35 PPM and the EPA Primary Air Quality Standard is 9 PPM (redrawn from Seinfeld, 1986).

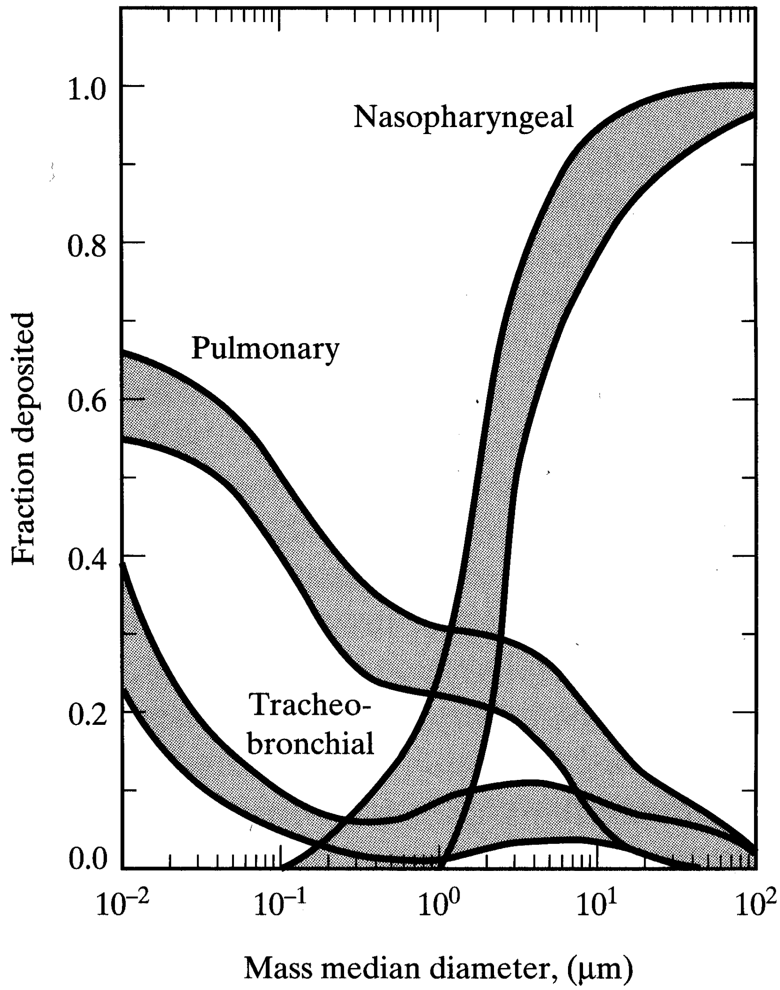


Figure 2.34 Predicted regional deposition of particles in the respiratory system for a tidal volumetric flow rate of 21. L/min. Shaded area indicates the variation resulting from two geometric standard deviations, 1.2 and 4.5 (redrawn from Perra and Ahmed, 1979).