CHAPTER 2
Blood: The Working Fluid

Blood is comprised of plasma, the liquid part, and cells, the solid part. Blood is a suspension of cells in plasma and about 40% of the total blood volume is cells. While blood has many functions, we will concern ourselves with those properties of interest to the hemodynamicist.

2.1 Blood Plasma

Plasma is mostly water (90-95%) with dissolved bicarbonate, chloride, phosporus, sodium, calcium, potassium, magnesium, urea, glucose and large proteins called albumin and α, β, and γ globulins.

One function of plasma is to transport dissolved CO_2 and O_2 gasses. Henry's law describes the relationship between pressure, solubility, and the number of gas molecules in a solution.

$$[g] = P \times S \qquad \text{Equation 2.1}$$

Where,

$[g] = \text{concentration of dissolved gas, mols/mL}$

$P = \text{pressure, mmHg}$

$S = \text{solubility coefficient, mols/mmHg mL}$

TABLE 2.1

Gas	Solubility
Oxygen	0.24
Carbon Dioxide	0.57
Carbon Monoxide	0.018
Nitrogen	0.012
Helium	0.008

2.2 Cells

Three main groups of cells exist in the blood – red and white cells, and platelets. Red blood cells are the oxygen carrying cells and are produced by the bone marrow. Hemoglobin, the oxygen carrying compound, makes up 95% of the RBC's dry weight.

Oxygen enters the blood by diffusion across lung membranes. Once in the blood, almost all the oxygen is transported by the hemoglobin located within the RBC. Hemoglobin allows 30 to 100 times the amount of oxygen transport than would occur by simple dissolved oxygen. Once at the tissue, oxygen diffuses into cells and reacts with various fuels to produce carbon dioxide. Figure 2-1 illustrates the "loading" of oxygen as the blood traverses the lung.
As the blood enters the lung, it has a partial pressure of 40 mmHg. The partial pressure of oxygen rises dramatically to a value near it's atmospheric value.

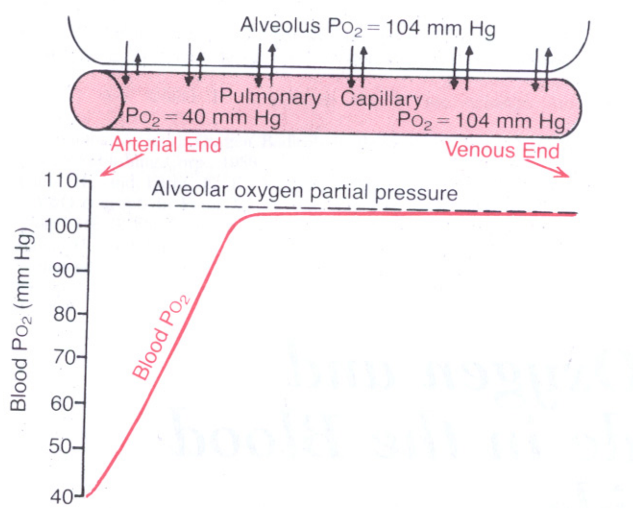
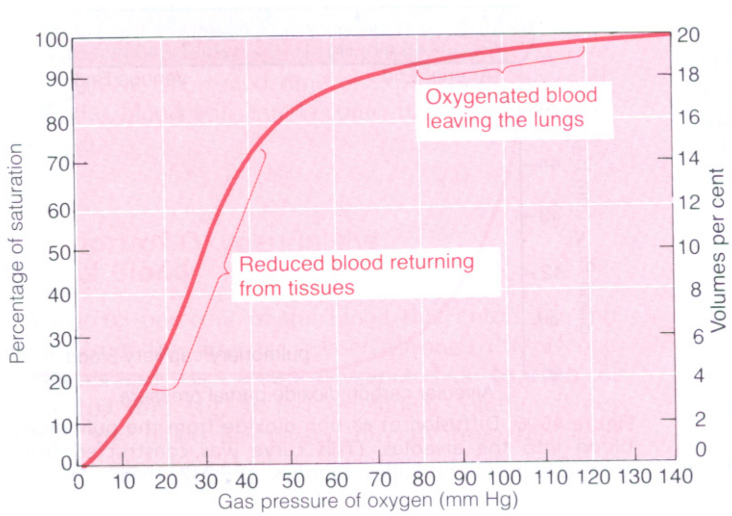


Figure 40–1. Uptake of oxygen by the pulmonary capillary blood. (The curve in this figure was constructed from data in Milhorn and Pulley: *Biophys. J.*, *8*:337, 1968.)

Figure 2-2 illustrates the oxygen saturation levels in both percent saturation (left axis) and volume percent (right axis). Volume percent is the volume of oxygen contained in a volume of blood.



Finally, Figure 2.3 illustrates the reduction in venous oxygen saturation as the energy demands of the body increase with exercise. In other words more oxygen is extracted in the tissue upon exercise.

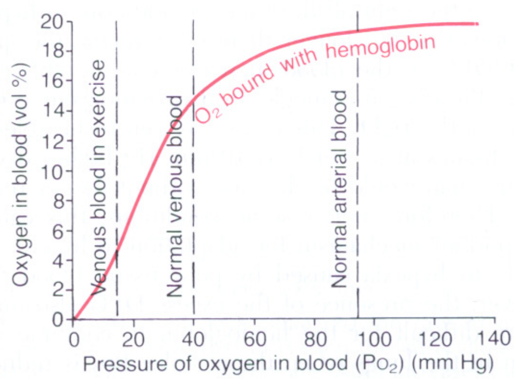


Figure 40–9. Effect of blood Po_2 on the quantity of oxygen bound with hemoglobin in each 100 milliliters of blood.

2.3 Viscosity

Viscosity relates to the internal friction due to molecular cohesion in a fluid. It is also the resistance to sliding motion of adjacent layers of a fluid when in motion. A Newtonian liquid is one where the coefficient of viscosity is constant at all rates of shear. For a tube,

$$\tau = \mu\left(\frac{d\upsilon}{dr}\right).$$

Where,

$\tau =$ shear stress in force/area

μ = viscosity

υ= fluid velocity

r = radius

Plasma approximates a Newtonian fluid, but when RBC's are added, the interactions between the cells cause the viscosity to be dependent on the the velocity gradient (shear rate). Figure 2.4 illustrates the effect of higher hematocrit (Hn) on the viscosity.