Functions of the Blood

18.1 Basic Concepts

Blood is an opaque red fluid consisting of the pale yellow plasma (called serum when the fibrinogen is removed) and the cells suspended in it - the red corpuscles (erythrocytes), the white corpuscles (leukocytes) and the platelets (thrombocytes). Blood has an important role in clinical diagnosis, because it is easy to collect and there are many diseases in which the blood composition and properties of the components are characteristically altered.

Functions of the Blood

Transport. Blood is primarily a medium by which substances are conveyed within the body. It transports the respiratory gases oxygen and carbon dioxide both in physical solution and in chemically bound form – O₂ from the lungs to the respiring tissues and CO₂ from the tissues to the lungs. It moves nutrients from the places where they are absorbed or stored to the sites of consumption. The metabolites produced there are transferred to the excretory organs or the places where they can be further utilized. Blood serves as a vehicle for the hormones, vitamins and enzymes produced by the body itself, taking them up at the sites of production or storage and carrying them – distributed throughout the intravascular space – to their target organs. Thanks to the high heat capacity of water, its chief component, blood distributes the heat produced by metabolism and disperses it into the environment by way of the lungs and respiratory passages and the exposed body surface.

Homeostasis. As the blood circulates through the body its composition and physical properties are continually monitored by certain organs and, if necessary, corrected so as to ensure constancy of the internal milieu. This condition of homeostasis – approximate constancy in the concentration of dissolved substances, in temperature and in pH – is a basic requirement for the normal functions of all cells.

Prevention of hemorrhage. Another important function of the blood lies in its capacity to counteract bleeding by the closing of small injured vessels and by coagulation (see pp. 419ff.).

Defense against foreign agents. The body is capable of making foreign bodies and pathogenic organisms harmless; this ability is associated primarily with phagocytic and antibody-forming blood cells (see pp. 425ff.).

Blood Volume

Blood accounts for about 6–8% of the weight of the body in adults, and in young children (because of their higher water content in general) 8–9%. In an adult this corresponds to a blood volume of 4–6 liters (normovolemia). An above-normal blood volume is called hypervolemia, and a subnormal volume is hypovolemia. The way this volume is measured is explained on p. 541, and its distribution among the different parts of the vascular system is described on p. 490.

Hematocrit

Definition and normal levels. The fraction of the blood volume made up of erythrocytes is called the hematocrit. In a healthy adult man it is 0.44–0.46, and in a woman 0.41–0.43. In the clinic hematocrit is still sometimes given in vol. % (ml cells/dl blood). A healthy person exhibits appreciable and maintained departures from this value only when adapted to high altitudes. The newborn hematocrit is about 20% higher, and that of small children is about 10% lower than that of women [6, 25].

To determine hematocrit (by Wintrobe’s method) the blood, having been prevented from clotting, is centrifuged for 10 minutes at about 1,000 g (g = relative acceleration due
Blood Plasma

Blood plasma is separated (by gravity) in standard hematocrit-tubes of small diameter. The blood cells, having higher specific gravity than the plasma, sink to the bottom; because the leukocytes are lighter than the erythrocytes, they form a thin whitish layer between the sedimented erythrocytes, and the plasma. Because of the special flow properties of the erythrocytes, the hematocrit values of the various organs differ, and there are differences among the venous, arterial and capillary values. The average whole-body hematocrit can be derived by multiplying by 0.9 the hematocrit obtained for cubital-vein blood with the Wintrobe method.

Hematocrit and viscosity of blood. Taking the viscosity of water as 1, the mean relative blood viscosity of healthy adults is 4.5 (3.5–5.4), and that of the blood plasma is 2.2 (1.9–2.6). The internal friction of the blood, its viscosity, increases more than proportionally as the hematocrit increases (cf. Fig. 20–3, p. 482).

Because resistance to flow rises linearly with viscosity, any pathological increase in hematocrit puts a greater load on the heart and can result in inadequate circulation through certain organs.

18.2 Blood Plasma

A liter of human plasma contains 900–910 g of water, 65–80 g of protein, and 20 g of substances of low molecular weight. The specific gravity of plasma is 1.025–1.029; its pH varies slightly (7.37–7.43) about a mean of 7.40 (arterial blood).

Fig. 18-1 is a diagram of the three great fluid compartments in the body, the blood-vascular system, the interstitial space (the spaces between cells) and the intracellular space. The interstitial fluid constitutes the environment of the mass of cells in the body. By way of the large surface of the capillary walls (highly permeable to water and electrolytes) it exchanges substances with the plasma. Because the exchange of water and small molecules between plasma and interstitial space is very rapid, the range within which the composition of the interstitial fluid can vary is small despite the considerable variations in uptake and release of substances by the cells. For example, experiments with heavy water (deuterium-labelled, D₂O) have shown that over 70% of the plasma fluid is exchanged with the interstitial fluid in one minute.

There are appreciable concentration differences between plasma and interstitial space only with respect to the proteins, for these molecules are so large that they cannot pass readily through the capillary membrane.

Plasma Electrolytes

Electrolyte concentrations. Table 18-1 and Fig. 18-2 summarize the ionic composition of plasma. Among the substances in the group called simply "organic acids" are lactic acid, the amino acids, citric acid and pyruvic acid.

It is preferable no longer to give concentration as w/v ratio (g/dl or mg/dl) but rather in terms of molarity (mol/liter) and normality or equivalent concentration (eq/liter = mol/valence · liter). When it is necessary to allow for the reduced volume of solvent in a solution in which the dissolved particles require a great deal of space, molality (mol/kg solvent) is often used as a measure of concentration (see Table 18-1).

Osmotic pressure. The concentration of dissolved substances in the plasma can be expressed by the osmotic pressure. That of normal plasma is about 7.3 atm (5,600 mm Hg = 745 kPa), which corresponds to a freezing-point depression of −0.54°C. Solutions with the same osmotic pressure as plasma are called isotonic, and by the same convention hypertonic solutions have higher, and hypotonic solutions lower osmotic pressure. Plasma is isotonic with a barely 1/3 molal solution of a nonelectrolyte. 96% of the osmotic pressure of blood is due to the presence of inorganic electrolytes, mainly sodium chlo-