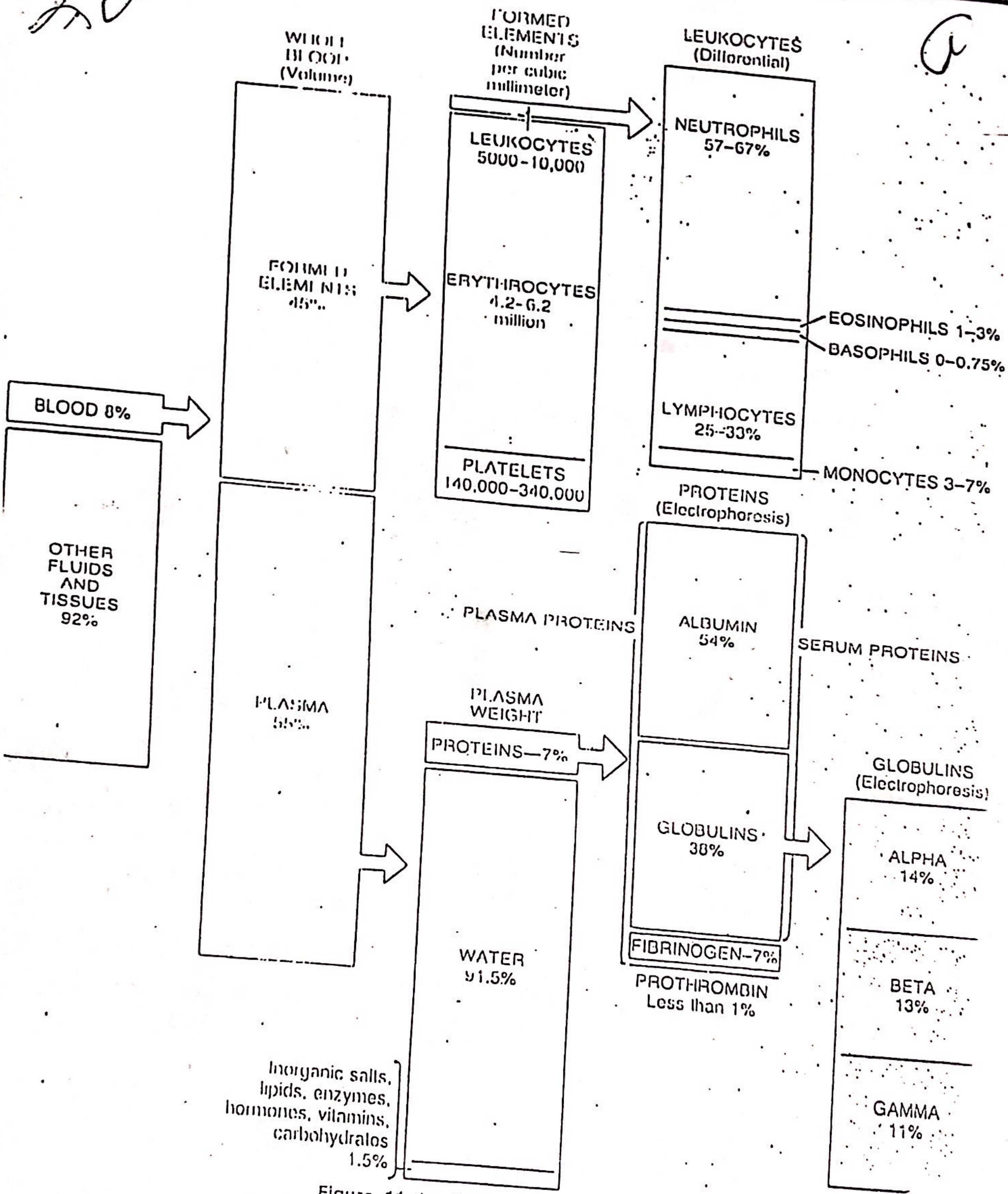

Figure 11–1. Composition of blood.

Table 13.2 The cellular elements of whole blood

Cell type	Site of production	Typical cell count (l^{-1})	Comments and function
Erythrocytes (red cells)	Bone marrow	5×10^{12} (men) 4.5×10^{12} (women)	Transport of O_2 and CO_2
Leukocytes (differential count)		7×10^9	
Granulocytes			
neutrophils	Bone marrow	5.0×10^9 (40–75%)	Phagocytes—engulf bacteria and other foreign particles
eosinophils	Bone marrow	100×10^6 (1–6%)	Congregate around sites of inflammation—have antihistamine properties; very short-lived in blood
basophils	Bone marrow	40×10^6 (<1%)	Circulating mast cells: produce histamine and heparin
Agranulocytes			
monocytes	Bone marrow	0.4×10^9 (2–10%)	Phagocytes, become macrophages when they migrate to the tissues
lymphocytes	Bone marrow, lymphoid tissue, thymus, spleen	1.5×10^9 (20–45%)	Production of antibodies
Platelets	Bone marrow	250×10^9	Aggregate at sites of injury and initiate hemostasis

Note that, while mean values are given, these are subject to considerable individual variation. The approximate percentage of individual types of leukocyte are given after the number per litre—this is called the differential white cell count.

Table 16.3 Constituents of Plasma

Constituent	Amount/Concentration*
pH	7.35 to 7.45
Water	*90% of plasma*
Electrolytes (inorganic)	*<1% of plasma*
Na^+	142 mEq/l (142 mmol/l)
K^+	4 mEq/l (4 mmol/l)
Ca^{2+}	5 mEq/l (2.5 mmol/l)
Mg^{2+}	3 mEq/l (1.5 mmol/l)
Cl^-	107 mEq/l (107 mmol/l)
HCO_3^-	27 mEq/l (27 mmol/l)
Phosphate (mostly HPO_4^{2-})	4 mEq/l (2 mmol/l)
SO_4^{2-}	1 mEq/l (0.5 mmol/l)
Gases	*about 1% of plasma*
CO_2	60 ml/100 ml plasma
O_2	0.2 ml/100 ml
N_2	0.9 ml/100 ml
Nutrients	*about 3% of plasma*
Glucose and other carbohydrates	100 mg/100 ml
Amino acids	40 mg/100 ml
Lipids	500 mg/100 ml
Cholesterol	150–250 mg/100 ml
Vitamins	traces
Trace elements	traces
Waste products	*about 1% of plasma*
Urea	<20 mg/100 ml
Creatinine	<1 mg/100 ml
Uric acid	5 mg/100 ml
Bilirubin	0.2–1.2 mg/100 ml
Proteins	*6% of plasma (2.5 mmol/1)*
Albumins	4.5 g/100 ml
Globulins	2.5 g/100 ml
Fibrinogen	0.3 g/100 ml
Hormones	*traces*

*Concentrations for some substances are expressed in both millimoles (mmol) and milliequivalents (mEq). One millimole is one-thousandth of a gram molecular weight of a substance. For substances that have a valence of 1, mEq and mmol are equal; for substances that have a valence of 2, 2 mEq equal 1 mmol.

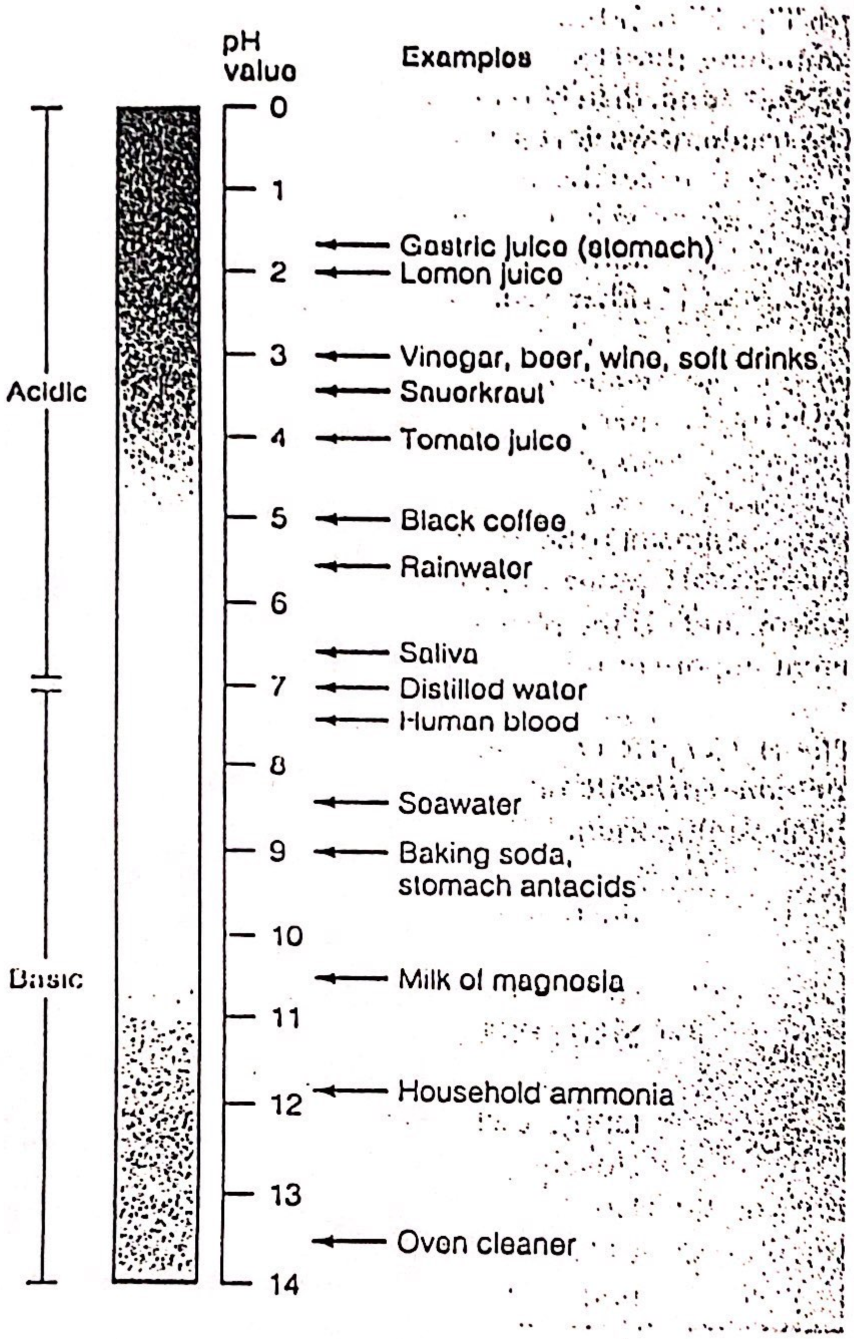

Figure 15-7 Comparison of pH Values of Common Solutions

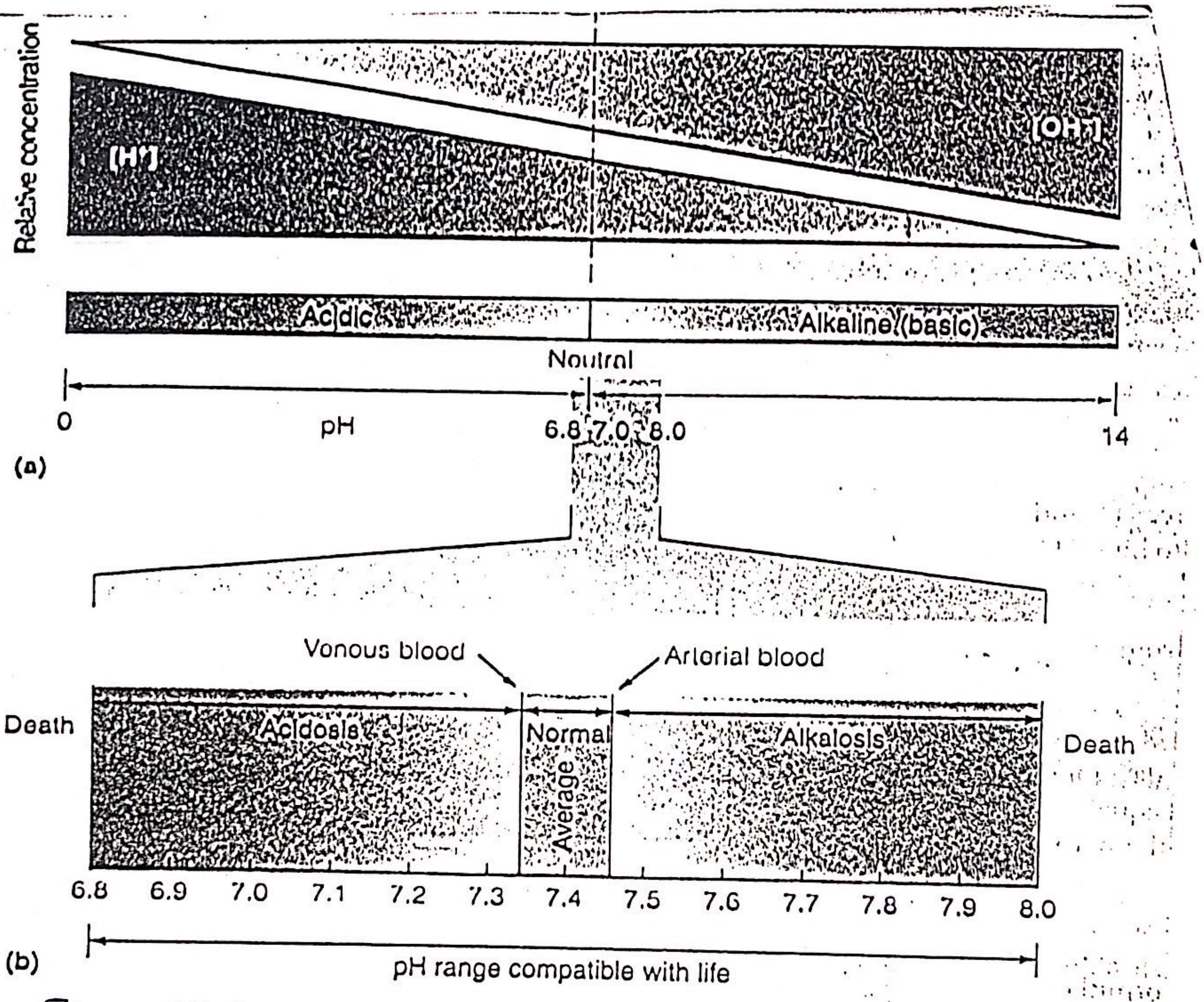

Figure 15-6 pH Considerations in Chemistry and Physiology
(a) Relationship of pH to the relative concentrations of H^+ and base (OH^-) under chemically neutral, acidic, and alkaline conditions. (b) Plasma pH range under normal, acidosis, and alkalosis conditions.

• The principal role of the blood,

The blood is a vital vehicle of communication between the tissues of multi-cellular organisms. Its numerous functions include the following:

(1) delivery of nutrients from gut to tissues;

(2) gas exchange: the carriage of oxygen from the lungs to the tissues, and carbon dioxide from the tissues to the lungs.;

(3) transport of the waste products of metabolism from the sites of production to the sites of disposal;

(4) carriage of hormones from endocrine glands to specific target tissues; and

(5) protection against invading organisms—its immunological role.

Table 13.1 Principal constituents of the plasma

Constituent	Quantity	Units	Remarks
Water	94.5	g l^{-1}	
Bicarbonate	25	mmoles l^{-1}	Important for the carriage of CO_2 and for H^+ buffering
Chloride	105	mmoles l^{-1}	The principal extracellular anion
Inorganic phosphate	1.1	mmoles l^{-1}	
Calcium	2.5	mmoles l^{-1}	This is total calcium; ionized calcium is about 1.5 mmoles l^{-1}
Magnesium	0.8	mmoles l^{-1}	
Potassium	4	mmoles l^{-1}	
Sodium	144	mmoles l^{-1}	The principal extracellular cation
Hydrogen ions	40	nmoles l^{-1}	This corresponds to a pH value of c. 7.4
Glucose	4.5	mmoles l^{-1}	Major source of metabolic energy, particularly for the CNS
Cholesterol	2.0	g l^{-1}	
Fatty acids (total)	3.0	g l^{-1}	
Total protein	70–85	g l^{-1}	
Albumin	45	g l^{-1}	Principal protein of the plasma; binds hormones and fatty acids
α-Globulins	7	g l^{-1}	
β-Globulins	8.5	g l^{-1}	
γ-Globulins	10.6	g l^{-1}	Immunoglobulins (antibodies)
Fibrinogen	3	g l^{-1}	Blood clotting
Prothrombin	1	g l^{-1}	Blood clotting
Transferrin	2.4	g l^{-1}	Iron transport

Note that these values are approximate mean values and that even in health there is considerable individual variation.

The concentration of osmotically active particles is usually expressed in osmoles. One osmole (osm) equals the gram-molecular weight of a substance divided by the number of freely moving particles that each molecule liberates in solution. The milliosmole (mosm) is 1/1000 of 1 osm.

If a solute is a nonionizing compound such as glucose. the osmotic pressure is a function of the number of glucose molecules present. If the solute ionizes & forms an ideal solution, each ion is an osmotically active particle. For example, NaCl would dissociate into Na+ & Cl- ions. so that each mole in solution would supply 2 osm. One mole of Na_2SO_4 would dissociate into Na-, Na+ & SO_4^{2-} , supplying 3 osm.

The osmolarity is the number of osomoles per liter of solution - e.g. plasma whereas the osmolality is the number of osmoles per kilogram of solvent. Therefore , osmolality is affected by the volume of the various solutes in the solution & the temperature. While osmolality is not.

The freezing point of normal human plasma averages -0.54 °C, which corresponds to an osmolal concentration in plasma of 290 mosm/L. Solutions that have the same osmolality as plasma are said to be isotonic : those with greater osmolality are hypertonic ; & those with lesser osmolality are hypotonic.

The circulating blood volume is about 7–8 per cent of body weight, so that for a 70 kg man blood volume will be around 5 liters, but for a newborn baby weighing 3.2 kg (7 lb), blood volume will only be around 250 ml—an important point to remember when considering a blood transfusion on a small baby. At any one time, assuming a blood volume of 5 liters, about 1 liter will be in the lungs, about 3 liters in the systemic venous circulation and the remaining liter in the heart, systemic arteries, arterioles, and capillaries (

Table 9.1 Approximate percentage distribution of the blood volume in an adult at rest

Veins	65%–75%
Arteries	10%–15%
Capillaries	5%
Heart	5%
Lungs	10%

VARIATIONS UNDER DIFFERENT PHYSIOLOCAL CONDITIONS

1. **SEX**: for males the blood volume is 10% higher than in females. This is due to greater number of RBc.

2. **PREGNANCY**: B.V. rises due to increase in **both** cells & plasma. In pregnant women B.V. increases on the average by about 20 to 30%, in the last few weeks of pregnancy.

3. **MUSCULAR EXPERCISE**: It raises B.V. probably due to contraction of spleen.

4. **POSTURE**: In erect posture there is about 15% diminution of total plasma. It passes out into the tissue spaces.

5. **BLOOD PRESSURE**: Rise of B.P. lowers B.V. by pressing out more fluid into the tissue spaces.

6. **AL TITUDE**: At higher altitude the B.V. will rise. Due to hypoxia the number of RBc will increase.

7. **ADERNALINE INJECTION**: Raises B.V. probably by contraction of spleen.

The plasma proteins generally are synthesized by the liver, with the exception of the gamma globulins, which are produced by lymphocytes.

Summary of the functions of plasma proteins

1 Transport functions (α- and β-globulins).

2 Defensive (immunoglobulins).

3 Reserve of body proteins

4 Osmotic function (albumin) through control of the exchange of fluid between blood and tissues

5 Viscosity of plasma is due mainly to fibrinogen and globulins.

6 Fibrinogen is the precursor of fibrin in the blood clot. Prothrombin is an α_2-globulin and most of the remaining clotting factors are β-globulins.

FUNCTIONS

Blood is a complex liquid that performs a number of critical functions.

1. It transports oxygen from the lungs to all cells of the body.
2. It transports carbon dioxide from the cells to the lungs.
3. It transports nutrients from the digestive organs to the cells.
4. It transports waste products from the cells to the kidneys, lungs, and sweat glands.
5. It transports hormones from endocrine glands to the cells.
6. It transports enzymes to various cells.
7. It regulates body pH through buffers and amino acids.
8. It plays a role in the regulation of normal body temperature because it contains a large volume of water (an excellent heat absorber and coolant).
9. It regulates the water content of cells, principally through dissolved sodium ions.
10. It prevents body fluid loss through the clotting mechanism.
11. It protects against toxins and foreign microbes through special combat-unit cells.

There are close to 1,400 different *plasma proteins* identified, which amounts to a total of about 6 to 8 g of proteins/dL. Proteins are needed as building blocks of cells and tissues; they function as enzymes, hormones, antibodies, and transporters; they contribute to plasma osmolality and acid base balance; and they serve as an energy source under limiting conditions.

See next page for more obvious typing

There are close to 1400 different plasma proteins identified, which amounts to a total of about 6 to 8 g of proteins/dL.

Proteins are needed as :-

1. building blocks of cells & tissues.
2. enzymes
3. hormones
4. antibodies
5. transporters
6. they contribute to plasma osmolality,
7. & acid-base balance.
8. they serve as energy source under limiting conditions.

TABLE 26.7 The Amino Acids Found in Proteins

Essential	Nonessential
Histidine	Alanine
Isoleucine	Arginine
Leucine	Aspartic acid
Lysine	Citrulline
Methionine	Glutamic acid
Phenylalanine	Glycine
Threonine	Hydroxyglutamic acid
Tryptophan	Hydroxyproline
Valine	Norleucine
	Proline
	Serine
	Tyrosine

cells, blood, body fluids, and body secretions. Enzymes and many hormones are proteins. Proteins are composed of amino acids and have molecular weights of a few thousand to a few hundred thousand. More than 20 common amino acids form the building blocks for proteins (Table 26.7). Of these, nine are considered essential and must be provided by the diet. Although the **nonessential amino acids** are also required for normal protein synthesis, the body can synthesize them from other amino acids.

Complete proteins are those that can supply all of the essential amino acids in amounts sufficient to support normal growth and body maintenance. Examples are eggs, poultry, and fish. The proteins in most vegetables and grains are called **incomplete proteins** because they do not provide all of the essential amino acids in amounts sufficient to sustain normal growth and body maintenance. Vegetarians need to eat a variety of vegetables and soy protein to avoid amino acid deficiencies.