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PRINCIPLES OF BIOCHEMISTRY: Mammalian Biochemistry

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about 3 percent protein; subcutaneous lymph, 0.25 percent; and liver lymph, as much as 6 percent. In each case the albumin/globulin ratio is considerably greater than that of plasma, generally of the order of 3:1 to 5:1. Lymph also contains sufficient fibrinogen and prothrombin to permit slow clotting (Chap. 1).

SPECIALIZED BODY FLUIDS

In addition to plasma, interstitial fluid, and lymph, the extracellular fluid compartment also contains a variety of highly specialized transcellular fluids, many of which are secreted by a variety of epithelial cells. The composition of some of these fluids is summarized in Table 5.1.

Secretion

Secretion of specialized fluids is generally accomplished by epithelial cells aligned in columnar fashion, bathed by interstitial fluid or plasma on one side and fluid of different composition on the opposite side. The differences in composition of the two fluids cannot be accounted for in terms of spontaneous diffusion, osmosis, or permeability. The secretory process generally operates against an osmotic, electrochemical, or hydrostatic gradient and requires the use of metabolically derived energy. The secretory cells are usually arranged so that the transported fluid generally leaves by a duct, and the pressure within this duct is independent of arterial pressure.

TABLE 5.1 Approximate pH and Concentrations of the Major Electrolytes of Extracellular Fluids*

Fluid	pH	$[Na^+]$	$[K^+]$	$[Ca^{2+}]$	$[Cl^-]$	$[HCO_3^-]$	Protein	Other
		meq per liter of water						
Plasma	7.35–7.45	144	4.5	5.0	103	28	18 meq/liter (6.0–8.0 g/dl)	Organic acids, 6 meq/liter
Edema fluid	7.4	135	3.3	3.5	105	30	<0.25 g/dl	
Synovial fluid	7.3–7.4	142	4		117	25	1.0 g/dl	
Cerebrospinal fluid	7.4	146	3.5–4.0	3.0	125	25	15–40 mg/dl	
Aqueous humor	7.4	140	4.7	3.5	108	28	50 mg/dl	
Tears	7.0–7.4	142	3–6		115	5–25	0.75 g/dl	
Sweat	4.5–7.5	<85	3–6	3–5	<85	0–10	Trace	
Saliva	6.4–7.0	20–40	15–25	3–8	20–40	10–20	Variable	
Parietal gastric juice	<1.0	0	7	0	162	0	0	H^+, 155 meq/liter
Gastric mucus	7.4–7.5	145	5		115	30	Variable	
Mixed gastric secretions	1–2	20–60	6–7		145	0	Variable	H^+, 60–120 meq/liter
Pancreatic juice	7–8	148	7	6	80	80	Variable	
Jejunal fluid	7.2–7.8	142	7–10		105	30	Variable	
Ileal fluid	7.6–8.2	100–140	10–50		80	75	Variable	
Bladder bile	5.6–7.2	130	7–10	7–15	40–90	0–15	Variable	Bile salts, 50–100 meq/liter
Liver bile	7.4–8.0	145	5	5	75–110	25–50	Variable	Bile salts, 10–20 meq/liter

*Only the values given for plasma represent the mean of a large number of samples. In some instances a range is shown; in others a single value is quoted although the given figure is subject to appreciable variation. Since the values have been obtained in many laboratories, employing different analytical methods and sampling procedures, only the general pattern may be considered meaningful. The values reported for plasma are expressed per liter of plasma and hence are slightly lower than values expressed per liter of plasma water shown in Fig. 5.1.

Mammalian secretions include milk, sweat, tears, cerebrospinal fluid, aqueous humor, and the fluids of the digestive tract. Selective absorption across the intestinal mucosa, the reabsorption of water and solutes in renal tubules, and secretion into the lumen of the distal renal tubules may all be regarded from the same viewpoint. Among the more dramatic instances of secretion are the elaboration of 0.16 N HCl by the stomach and the secretion of almost pure water by sweat glands.

The fundamental mechanisms of secretion may be of diverse types. In cells actively engaged in synthesizing and secreting proteins, the rough endoplasmic reticulum (Chap. G13) is highly developed. Studies of such secretory cells, e.g., the pancreas, reveal synthesis of secreted pancreatic proteins, i.e., the zymogens (Chap. G10), and of hormones (Chap. 11) on the rough endoplasmic reticulum and transfer of these molecules to the region of the Golgi apparatus, where they are packaged into condensing vacuoles derived from sacs in the Golgi apparatus. The enzymes of both the endoplasmic reticulum and membranes of the

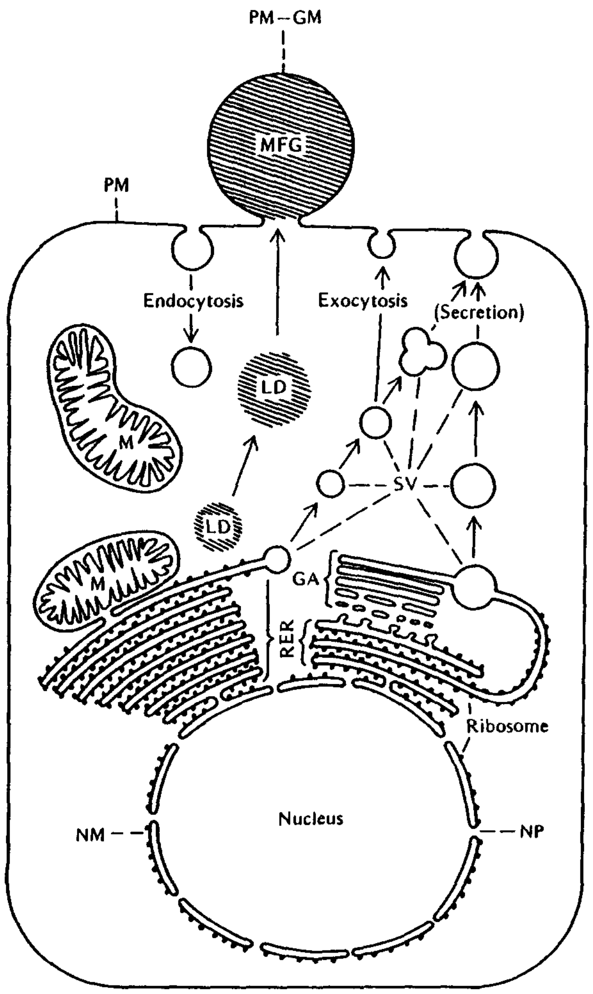

Figure 5.3 Schematic representation of a mammary secretory cell showing the components of the functionally continuous endomembrane system. NM = nuclear membrane; NP = nuclear pore; RER = rough endoplasmic reticulum; GA = Golgi apparatus; SV = secretory vesicle; M = mitochondria; PM = plasma membrane; PM-GM = plasma membrane enveloping a milk fat globule (MFG) being discharged from the cell. Lipid droplets (LD) appear to form near the endoplasmic reticulum and grow in size as they rise toward the apical portion of the cell. Within the cell the lipid droplets do not have a discernible membrane. [*From T. W. Keenan, D. J. Moore, and C. M. Huang, in B. L. Larson and V. R. Smith (eds.): Lactation: A Comprehensive Treatise, vol. II, Academic, New York, 1974, p. 191.*]

and does not respond readily to changes in plasma concentration. This is particularly striking in patients with parathyroid tumors, who show markedly elevated serum [Ca^{2+}] but normal spinal fluid [Ca^{2+}]. In general, the glucose concentration of spinal fluid is lower than that of plasma but rises and falls with changes in blood glucose levels. The concentration of amino acids is always appreciably lower in cerebrospinal fluid than in plasma.

Sweat

The secretion of sweat serves, through evaporation, to cool the body. When no visible perspiration is produced, the sweat glands release virtually pure water. This *insensible* perspiration may amount to 600 to 700 ml/day. The small amount of organic and inorganic material that accumulates on the skin under these conditions is probably associated with activity of sebaceous glands rather than with that of sweat glands. When visible sweat is elaborated, its volume and composition vary and are determined by rate of evaporation, previous fluid intake of the individual, external temperature and humidity, and hormonal factors. Volumes as large as 14 liters/day have been recorded. Both volume and salt content of sensible perspiration are influenced by acclimatization of the individual. Persons new to an environment that is hot and humid produce copious quantities of salt-laden perspiration; [Na^+] and [Cl^-] may be as high as 75 meq/liter. Acclimated individuals, however, produce smaller volumes with a lower salt concentration. Miners' or stokers' cramps result from salt loss in large volumes of perspiration and can be prevented by incorporation of small amounts of salt in drinking water. In cystic fibrosis, a congenital defect involving most or all of the glandular epithelial structures of the body, sweat and tears are characteristically rich in NaCl. This analytical difference is so striking as to be diagnostic. In hot weather, victims of this disease may succumb in a state resembling acute Addisonian crisis (Chap. 18), referable entirely to Na^+ loss, and corrected by NaCl administration.

When small volumes of visible perspiration are elaborated, its concentration of nonprotein nitrogenous materials slightly exceeds that of the plasma from which it is derived. This probably reflects evaporation of water from the elaborated sweat. However, sweat glands may possess an active mechanism for the concentration of lactic acid. The lactate concentration of the sweat of athletes far exceeds that present in plasma or urine. [K^+], [Mg^{2+}], [Ca^{2+}], etc., are of the order expected from those found in the plasma. Specific gravities of 1.002 to 1.005 for sweat have been reported, and the pH lies between 4.5 and 7.5.

Tears

The fluid that normally moistens the surface of the cornea is a mixed secretion of the lacrimal glands and of accessory sebaceous glands (the meibomian glands). Since the surface of the cornea is exposed during waking hours, there is constant evaporation of fluid on its surface, resulting in concentration of the tear fluid. Under stimulus with a slow rate of tear flow, the fluid is about 25 mosm

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Third Edition, 1964: Abraham White, Philip Handler, and Emil L. Smith. Japanese edition, 1966.

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Fifth Edition, 1973: Abraham White, Philip Handler, and Emil L. Smith. Japanese edition, 1974; Portuguese edition, 1976.

Sixth Edition, 1978: Abraham White, Philip Handler, Emil L. Smith, Robert L. Hill, and I. Robert Lehman. Japanese edition, 1979; Russian edition, 1981.

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