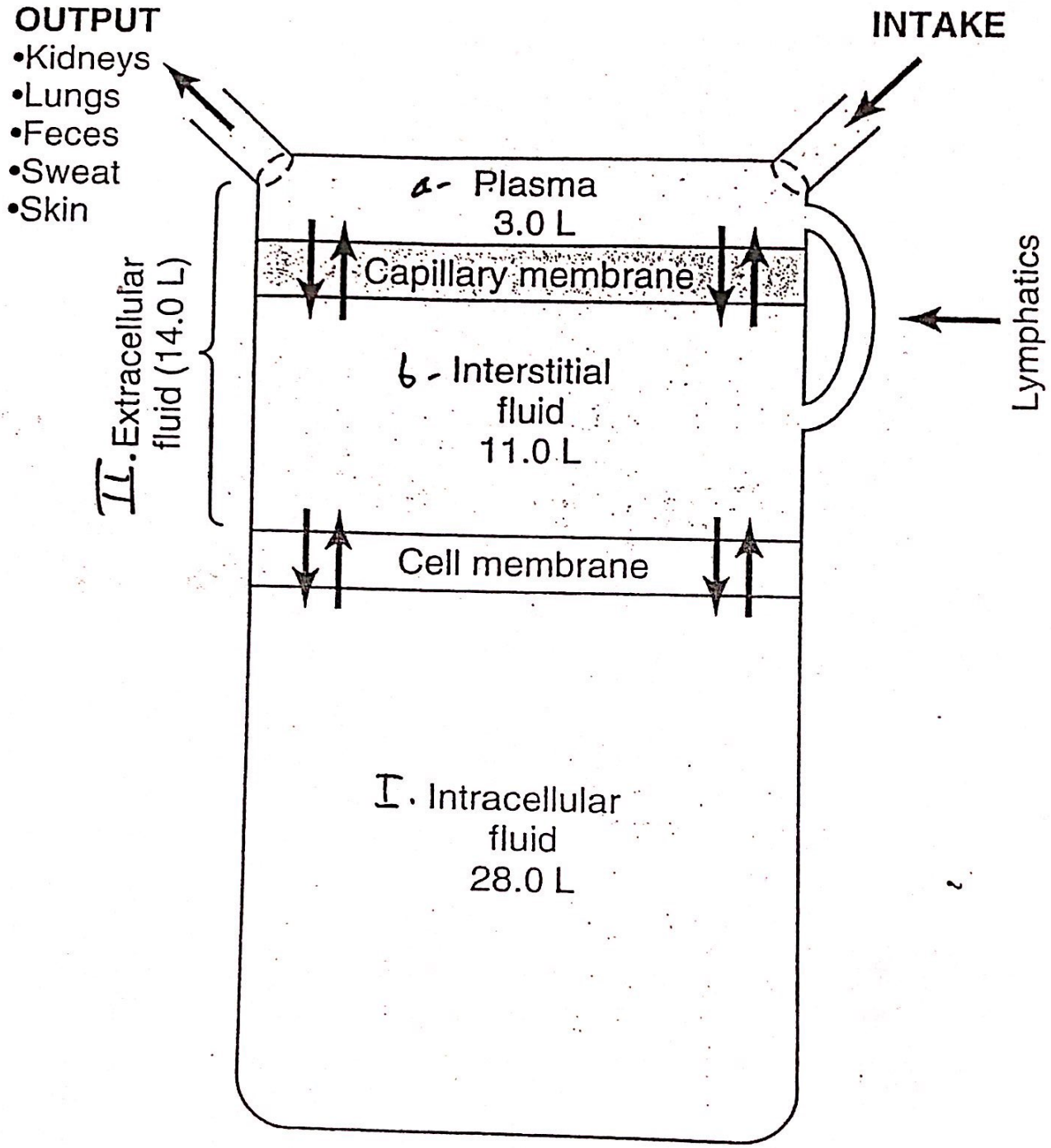



**Figure 25–1**

Summary of body fluid regulation, including the major body fluid compartments and the membranes that separate these compartments. The values shown are for an average 70-kilogram person.

About 60 per cent of the body of an adult male is water, the remaining 40 per cent being made up of fats, proteins, carbohydrates, and minerals. Females have a higher proportion of body fat and so total body water is about 50 per cent of their body weight. In both males and females, the lean body tissues are about 70 per cent water, 15 per cent fats, 12 per cent protein, 2 per cent nucleic acids, and 0.5 per cent carbohydrate (sugars). The remainder is made up of minerals of various kinds such as calcium, iron, magnesium, phosphate, potassium, and sodium. The chemical composition of the body given in Table 2.1 is an approximate average of all the tissues of an adult. The proportions of the various constituents vary between tissues and change during development.

Table 2.1 The approximate chemical constitution of the body (all values are expressed as percentage body weight)

| | |
|---|---|
| Oxygen | 65 |
| Carbon | 18 |
| Hydrogen | 10 |
| Nitrogen | 3.4 |
| Minerals total | 3.6 |
| $Na^+$ | 0.17 |
| $K^+$ | 0.28 |
| $Cl^-$ | 0.16 |
| $Mg^{2+}$ | 0.05 |
| $Ca^{2+}$ | 1.5 |
| Phosphorus | 1.2 |
| Sulfur | 0.25 |
| $Fe^{2+/3+}$ | 0.007 |
| $Zn^{2+}$ | 0.002 |

The body contains trace amounts of other elements in addition to those listed above.

Table 1–3. TBW (as percentage of body weight) in relation to age and sex.*

| Age | Male | Female |
|---|---|---|
| 10–18 | 59% | 57% |
| 18–40 | 61% | 51% |
| 40–60 | 55% | 47% |
| Over 60 | 52% | 46% |

=02 %.
= 10 %.
= 08 %.
= 06 %.

*Modified and reproduced, with permission, from Edelman IS, Liebman J: Anatomy of body water and electrolytes. *Am J Med* 1959;27:256.

TABLE 16.4

## COMPOSITION OF EXTRACELLULAR AND INTRACELLULAR FLUID COMPARTMENTS

(values in meq/l unless otherwise indicated)

| CONSTITUENTS AND PROPERTIES | EXTRACELLULAR FLUID | | INTRACELLULAR FLUID |
|---|---|---|---|
| | PLASMA | INTERSTITIAL FLUID | |
| Sodium | 142 | 145 | 10 |
| Potassium | 4 | 4 | 160 |
| Calcium | 5 | 5 | 2 |
| Magnesium | 2 | 2 | 26 |
| Chloride | 101 | 114 | 3 |
| Sulfate | 1 | 1 | 20 |
| Bicarbonate | 27 | 31 | 10 |
| Phosphate | 2 | 2 | 100 |
| Organic acids | 6 | 7 | — |
| Proteins | 16 | 1 | 65 |
| Glucose (av) | 90 mg% | 90 mg% | 0–20 mg% |
| Lipids (av) | 0.5 g% | — | — |
| pH | 7.4 | 7.4 | 6.7 |

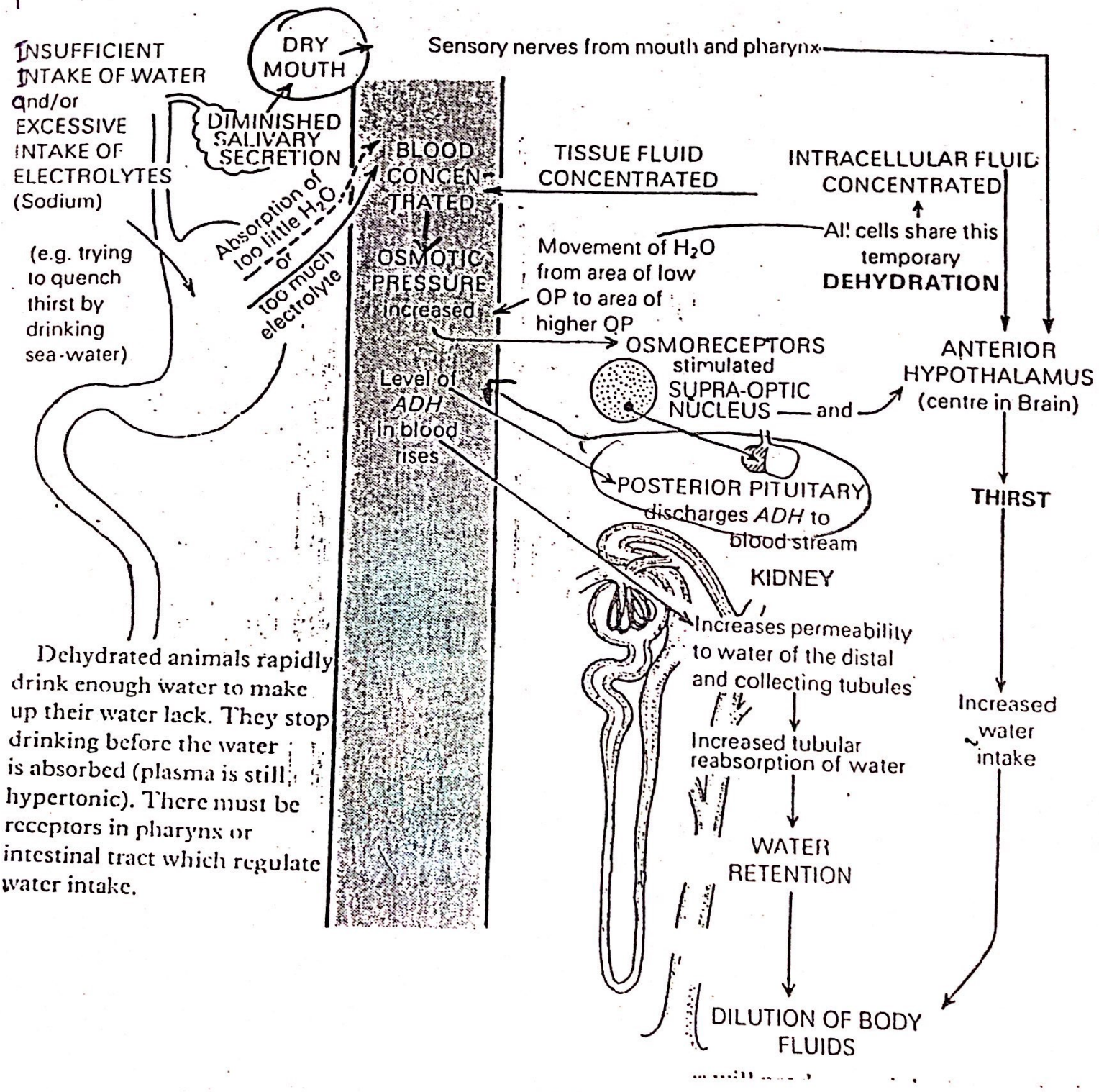
Table 23-1 Typical normal values for each portal of water entry and exit (with wide variations)

| Intake | | Output | |
|---|---|---|---|
| Ingested liquids | 1,500 ml | Kidneys (urine) | 1,400 ml (2) |
| Water in foods | 700 ml | Lungs (water in expired air) | 350 ml (1) |
| Water formed by catabolism | 200 ml | Skin | |
| | | By diffusion | 350 ml (1) |
| | | By sweat | 100 ml (1) |
| | | Intestines (in feces) | 200 ml (1) |
| TOTALS | 2,400 ml | | 2,400 ml |

Facultative Loss (2) Variable route of Loss

Obligatory Loss (1) Relatively Fixed

The **tonicity** or **osmolarity** of body fluids is controlled by **thirst** (which alters water intake) and *VASOPRESSIN* (*antidiuretic hormone, ADH*) released from the posterior pituitary gland (: . . ) (which alters water excretion by the kidney).




Dehydrated animals rapidly drink enough water to make up their water lack. They stop drinking before the water is absorbed (plasma is still hypertonic). There must be receptors in pharynx or intestinal tract which regulate water intake.

Characteristic symptoms result from dehydration. Water deficit gives rise to :

1. A shrunken appearance of the face and body.
2. The skin loses its elasticity and becomes hard and leathery.
3. There is rapid loss of body weight.
4. When the deficiency reaches such a degree that the water is no longer sufficient for removal of heat of metabolism, high fevers may occur.
5. As the condition worsens, circulatory failure develops.
6. Anuria results.
7. Acid products are retained leading to acidosis.
8. Cerebral disturbances, excitement, delirium and coma terminate the episode.

**dehydration**

If the homeodynamic mechanisms fail to operate properly, loss of fluid, electrolytes (ions), or both may occur. Three conditions may arise depending on the relative losses of fluid and electrolytes.

| | |
|---|---|
| Equal loss of fluid and electrolyte (*"isotonic dehydration"*) | There is a proportionate loss of fluid and electrolyte so that the total volume of ECF changes, but its osmotic pressure remains within normal limits. |
| Excessive fluid loss as compared to electrolytes (*"hypertonic dehydration"*) | More fluid than electrolyte is lost, with resulting concentration of the ECF. Water thus tends to be drawn from cells. |
| Excessive electrolyte loss as compared to fluids (*"hypotonic dehydration"*) | More solute than fluid is lost, therefore the ECF becomes diluted. Water thus tends to enter cells. |

## The osmotic pressure of the body fluids

When an aqueous solution is separated from pure water by a membrane that is permeable to water but not to the solute, water moves across the membrane into the solution by a process known as *osmosis*. This movement can be opposed by applying a hydrostatic pressure to the solution. The pressure that is just sufficient to prevent the uptake of water is known as the *osmotic pressure* of the solution.

The osmotic pressure of a solution is expressed as the *osmolality* and is related to the number of particles present per kilogram of solution, independent of their chemical nature. One gram mole of a nondissociating substance in one kilogram of solution exerts an osmotic pressure of 1 osmole. Thus the osmotic pressure exerted by a mole of glucose (relative molecular mass ($M_r$) 180) is the same as that exerted by a mole of albumin ($M_r$ 67 000). Aqueous salt solutions are an important exception to this rule: the salts separate into their constituent ions so that a solution of sodium chloride will exert an osmotic pressure double that of its molal concentration, i.e. a 100 mmol $kg^{-1}$ solution of sodium chloride in water will have an osmotic pressure of 200 mosmol $kg^{-1}$ of which a half is due to the sodium ions and half to the chloride ions.

TABLE 16.5

## A SUMMARY OF SYMPTOMS OF COMMON FLUID AND ELECTROLYTE DEFICITS AND EXCESSES

| CONDITION | HISTORY/LAB FINDINGS | SYMPTOMS | COMMENTS |
|---|---|---|---|
| ECF volume deficit | Decreased intake of fluid and electrolytes<br>Vomiting<br>Diarrhea<br>Rise of hematocrit* | Dry skin and mucous membranes<br>Oliguria (scanty urine production)<br>Weight loss (5–15%)<br>Lassitude | Appropriate response is isotonic infusion |
| ECF volume excess | Excessive isotonic IV infusion<br>Kidney disease<br>Congestive heart failure<br>Hematocrit decreases | Edema<br>Rapid weight gain | Appropriate response is to increase fluid output as by diuretic administration, or, give hypertonic NaCl and monitor ECF osmolarity |
| Sodium deficit | Heavy sweating with water intake<br>Adrenal disease<br>Hyponatremia (< 137 meq/L) | Mental confusion<br>Convulsions<br>Abdominal cramps<br>Diarrhea | Give NaCl, perhaps as salt pills<br>Raise ECF sodium levels |
| Sodium excess | Excessive isotonic IV infusion<br>Watery diarrhea<br>Inadequate water intake<br>Hypernatremia (> 147 meq/L) | Mania/convulsions<br>Dry mucous membranes<br>Oliguria | Administer hypotonic fluid/water by mouth |
| Potassium deficit | Diarrhea<br>Vomiting<br>Burns<br>Starvation<br>Low sodium diet<br>Hypokalemia (< 4 meq/L) | Flabby muscles<br>Anorexia<br>Cardiac arrhythmias | Administer $K^+$ as citrate or KCl |
| Potassium excess | Burns<br>Severe trauma<br>Kidney disease<br>Adrenal disease<br>Hyperkalemia (> 5.6 meq/L) | Oliguria → anuria<br>Diarrhea<br>Cardiac arrhythmias | Administer 10% calcium gluconate for heart<br>Hemodialysis |

* The hematocrit measures the relative volumes of blood cells and plasma. If fluid volume decreases, the number of cells increases in relative fashion and vice versa.

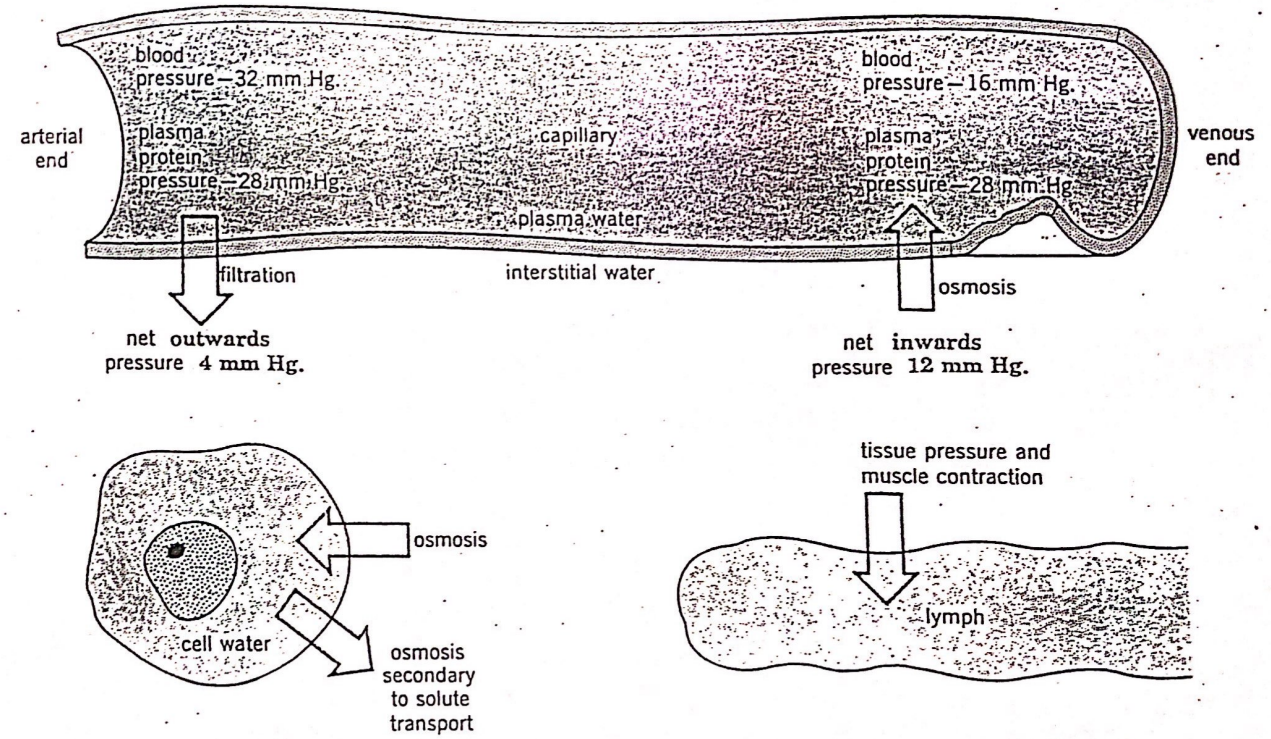



FIGURE 16.3
Some determinants of water movement between body water compartments.