Body fluid compartments

Objectives: By the end of this lecture, you will be able to:
- Describe the daily water intake and loss by the human body.
- Define body fluid compartments.
- List the important constituents of extracellular and intracellular compartments.
- Outline the regulation of fluid exchange and osmotic equilibrium between extracellular and intracellular fluid.
- Describe the volume and osmolality of Extracellular and Intracellular Fluids in abnormal States.

- Outline the fluids used in clinical practice.
Daily Intake of Water
(1) it is ingested in the form of liquids or water in the food, which together normally add about 2100 ml/day to the body fluids.
(2) it is synthesized in the body as a result of oxidation of carbohydrates, adding about 200 ml/day.
This provides a total water intake of about 2300 ml/day.
Daily Loss of Body Water

(1) Insensible Water Loss. about 700 ml/day. the average water loss by diffusion through the skin is about 300 to 400 ml/day.
through the respiratory tract averages about 300 to 400 ml/day.

(2) Fluid Loss in Sweat. about 100 ml/day.

(3) Water Loss in Feces. (100 ml/day) normally is lost in the feces.

(4) Water Loss by the Kidneys. urine volume can be as low as 0.5 L/day in a dehydrated person.
Body Fluid Compartments
two compartments: the **extracellular fluid** and the **intracellular fluid**. The extracellular fluid is divided into the **interstitial fluid** and the **blood plasma**.

**transcellular fluid**; All the transcellular fluids together constitute about 1 to 2 liters (includes fluid in the synovial, peritoneal, pericardial, and intraocular spaces, as well as the cerebrospinal fluid) . In the average 70-kilogram adult human, the total body water is about 60 per cent of the body weight, or about 42 liters.

Intracellular Fluid Compartment
About 28 of the 42 liters of fluid in the body are inside the 75 trillion cells and are collectively called the **intracellular fluid**. Thus, the intracellular fluid constitutes about 40 per cent of the total body weight in an “average” person.
Extracellular Fluid Compartment
All the fluids outside the cells are collectively called the *extracellular fluid*. Together these fluids account for about **20 per cent of the body weight, or about 14 liters** in a normal 70-kilogram adult.
the *interstitial fluid*, which makes up more than **three fourths** of the extracellular fluid, and the *plasma*, which makes up almost **one fourth** of the extracellular fluid, or about **3 liters**. The plasma is the noncellular part of the blood;

Blood Volume
Blood contains both extracellular fluid (the fluid in plasma) and intracellular fluid (the fluid in the red blood cells). The average blood volume of adults is about **7 per cent of body weight, or about 5 liters**. About 60 per cent of the blood is plasma and 40 per cent is red blood cells.
Important constituents Of Extracellular fluid:

The extracellular fluid, including the plasma and the interstitial fluid, contains large amounts of sodium and chloride ions, reasonably large amounts of bicarbonate ions, but only small quantities of potassium, calcium, magnesium, phosphate, and organic acid ions. This allows the cells to remain continually bathed in a fluid that contains the proper concentration of electrolytes and nutrients for optimal cell function.
Important Constituents of the Intracellular Fluid

The intracellular fluid is separated from the extracellular fluid by a cell membrane that is highly permeable to water but not to most of the electrolytes in the body. In contrast to the extracellular fluid, the intracellular fluid contains ions large amounts of potassium and phosphate ions plus moderate quantities of magnesium and sulfate ions. Also, cells contain large amounts of protein, almost four times as much as in the plasma. only small quantities of sodium and chloride ions and almost no calcium.
Basic Principles of Osmosis and Osmotic Pressure

Osmosis is the net diffusion of water across a selectively permeable membrane from a region of high water concentration to one that has a lower water concentration.
whenever there is a higher concentration of solute on one side of the cell membrane, water diffuses across the membrane toward the region of higher solute concentration.

Thus, if a solute such as sodium chloride is added to the extracellular fluid, water rapidly diffuses from the cells through the cell membranes into the extracellular fluid until the water concentration on both sides of the membrane becomes equal.

Conversely, if a solute such as sodium chloride is removed from the extracellular fluid, water diffuses from the extracellular fluid through the cell membranes and into the cells.
Relation Between Moles and Osmoles.
the water concentration of a solution depends on the number of solute particles in the solution.
The total number of particles in a solution is measured in **osmoles**.
One osmole (osm) is equal to 1 mole (mol) \((6.02 \times 10^{23})\) of solute particles.
a solution containing 1 mole of glucose in each liter has a concentration of 1 osm/L.

Thus, the term osmole refers to the number of osmotically active particles in a solution rather than to the molar concentration.

The term **milliosmole** (mOsm), which equals 1/1000 osmole, is commonly used.
Osmolality and Osmolarity.

The osmolal concentration of a solution is called **osmolality** when the concentration is expressed as **osmoles per kilogram of water**; it is called **osmolarity** when it is expressed as **osmoles per liter of solution**.
Osmotic Pressure.

Osmosis of water molecules across a selectively permeable membrane can be opposed by applying a pressure in the direction opposite that of the osmosis. The precise amount of pressure required to prevent the osmosis is called the *osmotic pressure*.

The higher the osmotic pressure of a solution, the lower the water concentration and the higher the solute concentration of the solution.
Relation Between Osmotic Pressure and Osmolarity.

The osmotic pressure of a solution is directly proportional to the concentration of osmotically active particles in that solution.

For example, one molecule of albumin with a molecular weight of 70,000 has the same osmotic effect as one molecule of glucose with a molecular weight of 180. One molecule of sodium chloride, however, has two osmotically active particles, \( \text{Na}^+ \) and \( \text{Cl}^- \), and therefore has twice the osmotic effect of either an albumin molecule or a glucose molecule.

The osmotic pressure of a solution is proportional to its osmolarity.

For each milliosmole concentration gradient across the cell membrane, 19.3 mm Hg osmotic pressure is exerted.
Osmolarity of the Body Fluids.

The total osmolarity of each of the three compartments is about 300 mOsm/L, with the plasma being about 1 mOsm/L greater than that of the interstitial and intracellular fluids. The slight difference between plasma and interstitial fluid is caused by the osmotic effects of the plasma proteins, which maintain about 20 mm Hg greater pressure in the capillaries than in the surrounding interstitial spaces.

Osmotic Equilibrium Is Maintained Between Intracellular and Extracellular Fluids.
Volume and Osmolality of Extracellular and Intracellular Fluids in Abnormal States

Ingestion of water

Dehydration

- Intravenous infusion of different types of solutions

Loss of large amounts of fluid from the gastrointestinal tract, and loss of abnormal amounts of fluid by sweating or through the kidneys.
basic principles are kept in mind:

1. *Water moves rapidly across cell membranes*; therefore, the osmolarities of intracellular and extracellular fluids remain almost exactly equal to each other except for a few minutes after a change in one of the compartments.

2. *Cell membranes are almost completely impermeable to many solutes*; therefore, the number of osmoles in the extracellular or intracellular fluid generally remains constant unless solutes are added to or lost from the extracellular compartment.
Fluids used in clinical practice:

(1) Isotonic fluids:

If a cell is placed in a solution of impermeant solutes having an osmolarity of 282 mOsm/L, such a solution is said to be "isotonic" because it neither shrinks nor swells the cells.

Examples of isotonic solutions include a 0.9 per cent solution of sodium chloride or a 5 per cent glucose solution. These solutions are important in clinical medicine because they can be infused into the blood without the danger of upsetting osmotic equilibrium between the intracellular and extracellular fluids.
(2) Hypotonic fluid:
If a cell is placed into a *hypotonic* solution that has a lower concentration of impermeant solutes (less than 282 mOsm/L), water will diffuse into the cell, causing it to swell; water will continue to diffuse into the cell, diluting the intracellular fluid while also concentrating the extracellular fluid until both solutions have about the same osmolarity. Solutions of sodium chloride with a concentration of less than 0.9 per cent are hypotonic and cause cells to swell.
(3) Hypertonic fluid: If a cell is placed in a *hypertonic* solution having a higher concentration of impermeant solutes, water will flow out of the cell into the extracellular fluid, concentrating the intracellular fluid and diluting the extracellular fluid. In this case, the cell will shrink until the two concentrations become equal. Sodium chloride solutions of greater than 0.9 per cent are hypertonic.
Effect of Adding Saline Solution to the Extracellular Fluid

If an *isotonic* saline solution is added to the extracellular fluid compartment, the osmolarity of the extracellular fluid does not change; therefore, no osmosis occurs through the cell membranes. The only effect is an increase in extracellular fluid volume. The sodium and chloride largely remain in the extracellular fluid because the cell membrane behaves as though it were virtually impermeable to the sodium chloride.
If a *hypertonic* solution is added to the extracellular fluid:

the *extracellular osmolarity increases* and causes osmosis of water out of the cells into the extracellular compartment. Again, almost all the added sodium chloride remains in the extracellular compartment, and fluid diffuses from the cells into the extracellular space to achieve osmotic equilibrium. The net effect is an increase in extracellular volume (greater than the volume of fluid added), a decrease in intracellular volume, and a rise in osmolarity in both compartments.
If a hypotonic solution is added to the extracellular fluid:

the osmolarity of the extracellular fluid decreases and some of the extracellular water diffuses into the cells until the intracellular and extracellular compartments have the same osmolarity. Both the intracellular and the extracellular volumes are increased by the addition of hypotonic fluid, although the intracellular volume increases to a greater extent.

Glucose and Other Solutions Administered for Nutritive Purposes