2.2. The body's fluid compartments

The chemical reactions of life take place in aqueous solutions. The dissolved substances in a solution are called solutes. In the human body, solutes vary in different parts of the body, but may include proteins—including those that transport lipids, carbohydrates, and, very importantly, electrolytes. Often in medicine, a mineral dissociated from a salt that carries an electrical charge (an ion) is called and electrolyte. For instance, sodium ions (Na+) and chloride ions (Cl–) are often referred to as electrolytes.

In the body, water moves through semi-permeable membranes of cells and from one compartment of the body to another by a process called osmosis. Osmosis is basically the diffusion of water from regions of higher concentration to regions of lower concentration, along an osmotic gradient across a semi-permeable membrane. As a result, water will move into and out of cells and tissues, depending on the relative concentrations of the water and solutes found there. An appropriate balance of solutes inside and outside of cells must be maintained to ensure normal function.

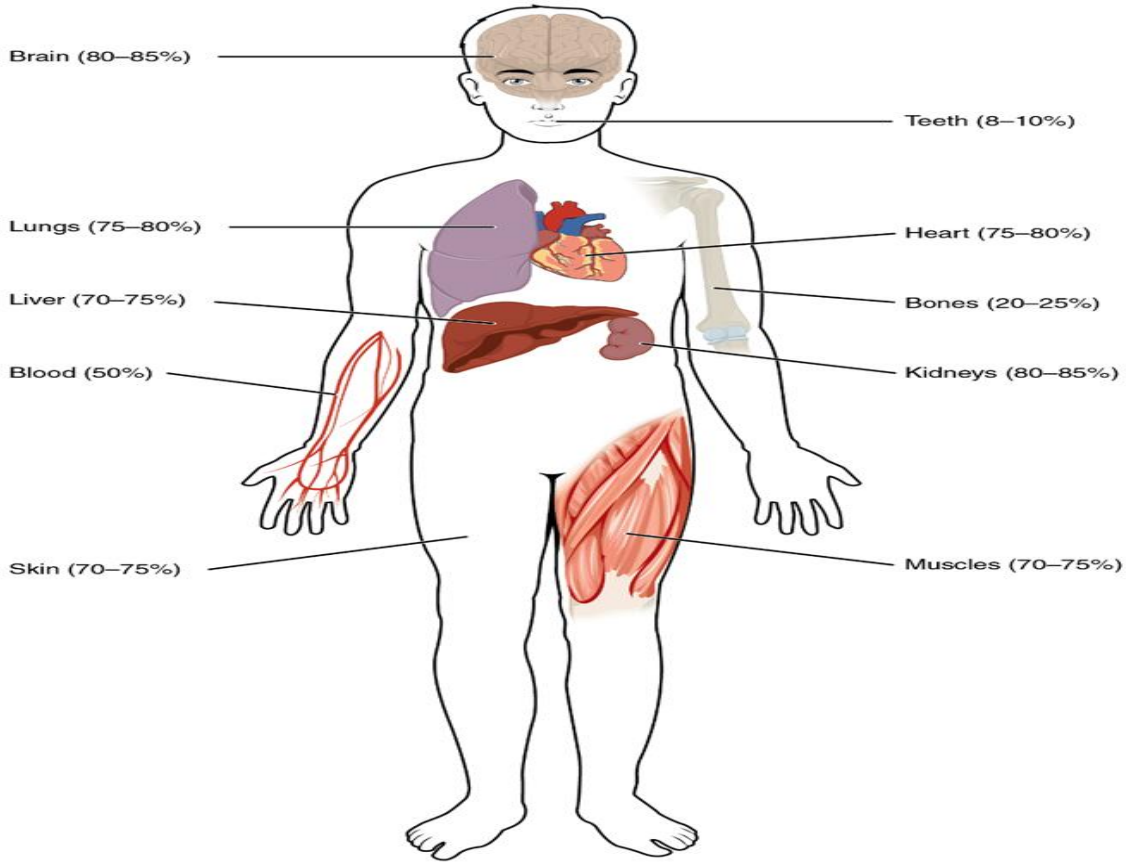

Figure 1. Water Content of the Body's Organs and Tissues Water content varies in different body organs and tissues, from as little as 8 percent in the teeth to as much as 85 percent in the brain.

Human beings are mostly water, ranging from about 75 percent of body mass in infants to about 50–60 percent in adult men and women, to as low as 45 percent in old age. The percent of body water changes with development, because the proportions of the body given over to each organ and to muscles, fat, bone, and other tissues change from infancy to adulthood. Your brain and kidneys have the highest proportions of water, which composes 80–85 percent of their masses. In contrast, teeth have the lowest proportion of water, at 8–10 percent.

BODY FLUID COMPARTMENTS

In a 70-kg adult man, the total body water is about 60% of the body weight, or about 42 liters. The total body fluid is distributed mainly between two compartments:

-Intracellular fluid.

-Extracellular fluid.

a) Interstitial fluid.

b) Blood plasma.

INTRACELLULAR FLUID COMPARTMENT:

- Intracellular fluid is the body fluids inside the cells.
- It constitutes about 40% of the total body weight (28 liters) in an "average" person.
- The intracellular fluid contains only small quantities of sodium and chloride ions and almost no calcium ions. Instead, it contains large amounts of potassium and phosphate ions plus moderate quantities of magnesium and sulfate ions.
- Cells contain large amounts of protein—almost four times as much as in the plasma.

EXTRACELLULAR FLUID COMPARTMENT (INTERNAL ENVIRONMENT):

- It includes all the fluids outside the cells.
- In the extracellular fluid are the ions and nutrients needed by the cells to maintain life. Thus, all cells live in essentially the same environment—the extracellular fluid. For this reason, the extracellular fluid is also called the internal environment of the body.
- It accounts for about 20% of the body weight, or about 14 liters in a 70-kg man.
- The two largest compartments of the extracellular fluid are:
  a. Interstitial fluid, which makes up more than three-fourths (11 liters) of the extracellular fluid.
  b. 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; it exchanges substances continuously with the interstitial fluid through the pores of the capillary membranes. These pores are highly permeable to almost all solutes in the extracellular fluid, except the proteins. Therefore, the extracellular fluids are 1 constantly mixing so the plasma and interstitial fluids have about the same composition, except for proteins, which have a higher concentration in the plasma. The concentrations of ions in interstitial fluid and plasma are considered to be about equal.

- Extracellular fluid contains large amounts of sodium and chloride ions and reasonably large amounts of bicarbonate ions but only small quantities of potassium, calcium, magnesium, phosphate, and organic acid ions.

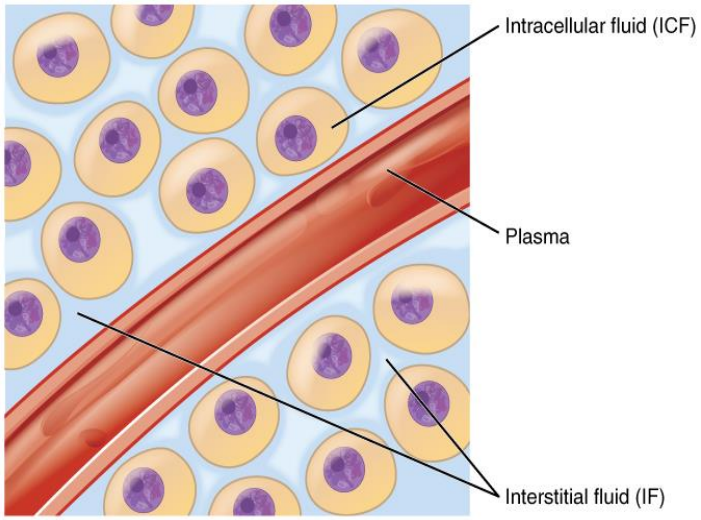

Figure 2. Fluid Compartments in the Human Body The intracellular fluid (ICF) is the fluid within cells. The interstitial fluid (IF) is part of the extracellular fluid (ECF) between the cells. Blood plasma is the second part of the ECF. Materials travel between cells and the plasma in capillaries through the IF.

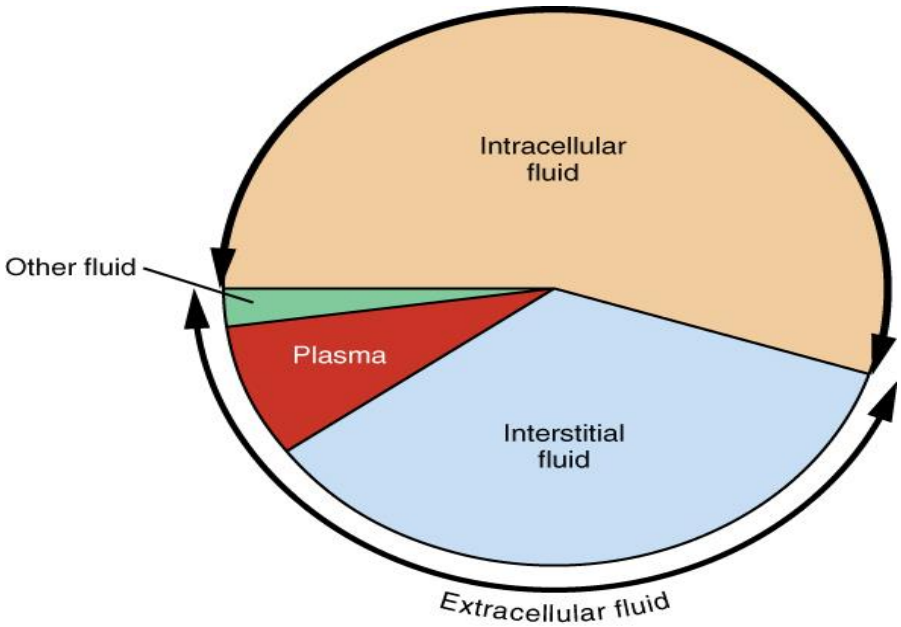

Figure 3.A Pie Graph Showing the Proportion of Total Body Fluid in Each of the Body's Fluid Compartments Most of the water in the body is intracellular fluid. The second largest volume is the interstitial fluid, which surrounds cells that are not blood cells.

Body Fluid Composition:

The composition of tissue fluid depends upon the exchanges between the cells in the biological tissue and the blood. This means that fluid composition varies between body compartments.

1.Intracellular Fluid Composition:

The cytosol or intracellular fluid consists mostly of water, dissolved ions, small molecules, and large, water-soluble molecules (such as proteins). This mixture of small molecules is extraordinarily complex, as the variety of enzymes that are involved in cellular metabolism is immense.

These enzymes are involved in the biochemical processes that sustain cells and activate or deactivate toxins. Most of the cytosol is water, which makes up about 70% of the total volume of a typical cell. The pH of the intracellular fluid is 7.4. The cell membrane separates cytosol from extracellular fluid, but can pass through the membrane via specialized channels and pumps during passive and active transport.

The concentrations of the other ions in cytosol or intracellular fluid are quite different from those in extracellular fluid. The cytosol also contains much higher amounts of charged macromolecules, such as proteins and nucleic acids, than the outside of the cell.

In contrast to extracellular fluid, cytosol has a high concentration of potassium ions and a low concentration of sodium ions. The reason for these specific sodium and potassium ion concentrations are Na+/K ATPase pumps that facilitate the active transport of these ions. These pumps transport ions against their concentration gradients to maintain the cytosol fluid composition of the ions.

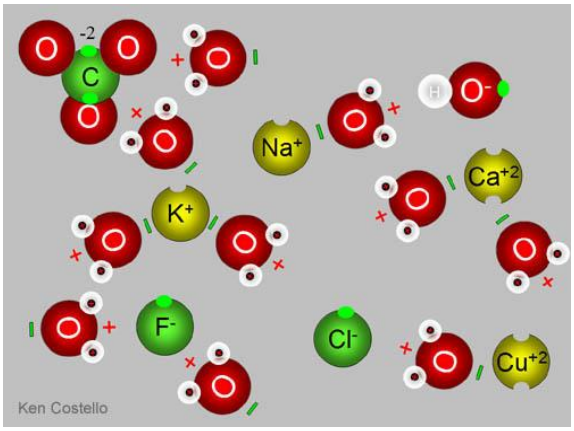

Figure 4.: Ions in solution

2.Extracellular Fluid Composition:

The extracellular fluid is mainly cations and anions. The cations include: sodium (Na+ = 136-145 mEq/L), potassium (K+ = 3.5-5.5 mEq/L) and calcium (Ca2+ = 8.4-10.5 mEq/L). Anions include: chloride (mEq/L) and hydrogen carbonate (HCO3- 22-26 mM). These ions are important for water transport throughout the body.

Plasma is mostly water (93% by volume) and contains dissolved proteins (the major proteins are fibrinogens, globulins, and albumins), glucose, clotting factors, mineral ions (Na+, Ca++, Mg++,

HCO_3^- Cl^- etc.), hormones and carbon dioxide (plasma being the main medium for excretory product transportation). These dissolved substances are involved in many varied physiological processes, such as gas exchange, immune system function, and drug distribution throughout the body.

Fluid Movement

Extracellular fluid is separated among the various compartments of the body by membranes. These membranes are hydrophobic and repel water; however, there are a few ways that fluids can move between body compartments. There are small gaps in membranes, such as the tight junctions, that allow fluids and some of their contents to pass through membranes by way of pressure gradients.

Formation of Interstitial Fluid

Hydrostatic pressure is generated by the contractions of the heart during systole. It pushes water out of the small tight junctions in the capillaries. The water potential is created due to the ability of the small solutes to pass through the walls of capillaries.
This buildup of solutes induces osmosis. The water passes from a high concentration (of water) outside of the vessels to a low concentration inside of the vessels, in an attempt to reach an equilibrium. The osmotic pressure drives water back into the vessels. Because the blood in the capillaries is constantly flowing, equilibrium is never reached.

The balance between the two forces differs at different points on the capillaries. At the arterial end of a vessel, the hydrostatic pressure is greater than the osmotic pressure, so the net movement favors water and other solutes being passed into the tissue fluid.

At the venous end, the osmotic pressure is greater, so the net movement favors substances being passed back into the capillary. This difference is created by the direction of the flow of blood and the imbalance in solutes created by the net movement of water that favors the tissue fluid.

Removal of Interstitial Fluid

The lymphatic system plays a part in the transport of tissue fluid by preventing the buildup of tissue fluid that surrounds the cells in the tissue. Tissue fluid passes into the surrounding lymph vessels and eventually rejoins the blood.

Sometimes the removal of tissue fluid does not function correctly and there is a buildup, which is called edema. Edema is responsible for the swelling that occurs during inflammation, and in certain diseases where the lymphatic drainage pathways are obstructed.