Body Fluid

Body is formed by solids and fluids; the fluid part forms more than 2/3 of the whole body. The maintenance of a relatively constant volume and a stable composition of the body fluids are essential for homeostasis. The relative constancy of the body fluids is remarkable because there is continuous exchange of fluid and solutes with the external environment, as well as within the different body compartments.

Water forms most of the fluid part of the body, plays a large part in normal body functions. Drinking enough water is essential for physiological processes such as circulation, metabolism, temperature regulation, and waste removal. Water is the main constituent of cells, tissues and organs; and is vital for life. It is the medium in which all transport systems function, allowing exchanges between cells, interstitial fluid and capillaries. Water maintains the vascular volume and allows blood circulation, which is essential for the function of all organs and tissues.

Daily intake of water

Water is added to the body by two major sources:

1. It is ingested in the form of liquids or water in food, which together normally adds about 2100 ml/day to the body fluids.
2. It is synthesized in the body by oxidation of carbohydrates, adding about 200 ml/day.

These mechanisms provide a total water intake of about 2300 ml/day. However, intake of water is highly variable among different people and even within the same person on different days, depending on climate, habits, and level of physical activity.

Daily loss of body water

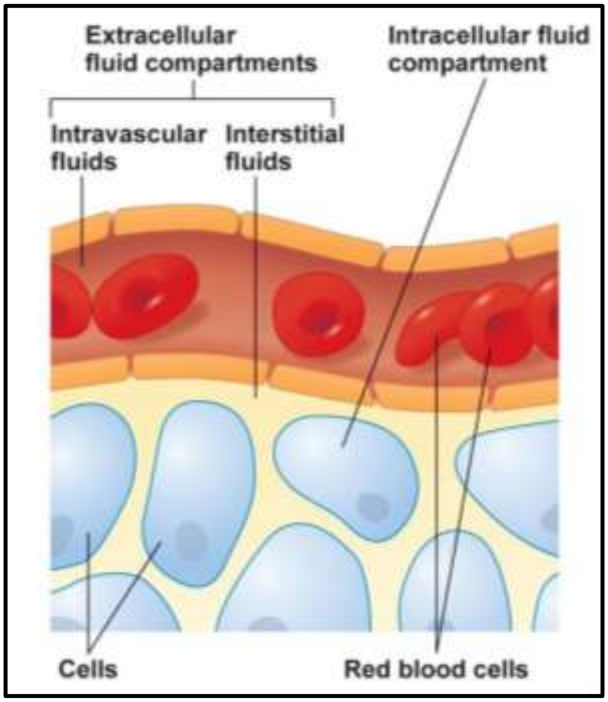
- ***Insensible Water Loss*:** Some water losses cannot be specifically regulated. For example, humans experience a continuous loss of water by evaporation from the respiratory tract and diffusion through the skin, which together account for about 700 ml/day of water loss under normal conditions. It occurs continually in all living humans.
- Insensible water loss through the skin occurs independently of sweating and is present even in people who are born without sweat glands; the average water loss by diffusion through the skin is about 300 -400 ml/day. This loss is minimized by the cornified layer of the skin, which provides a barrier against excessive loss by diffusion.
- ***Fluid Loss in Sweat*:** The amount of water lost by sweating is highly variable, depending on physical activity and environmental temperature. The volume of sweat normally is about (100 ml/day), but in very hot weather or during heavy exercise fluid loss in sweat occasionally increases to 1-2 L/hour. This fluid loss would rapidly deplete the body fluids if intake were not also increased by activating the thirst mechanism.
- ***Water Loss in Feces*:** Only a small amount of water (100 ml/day) normally is lost in the feces. This loss can increase to several liters a day in people with severe diarrhea. For this reason, severe diarrhea can be life threatening if not corrected in a few days.
- ***Water Loss by the Kidneys*:** The remaining water loss from the body occurs in the urine excreted by the kidneys.

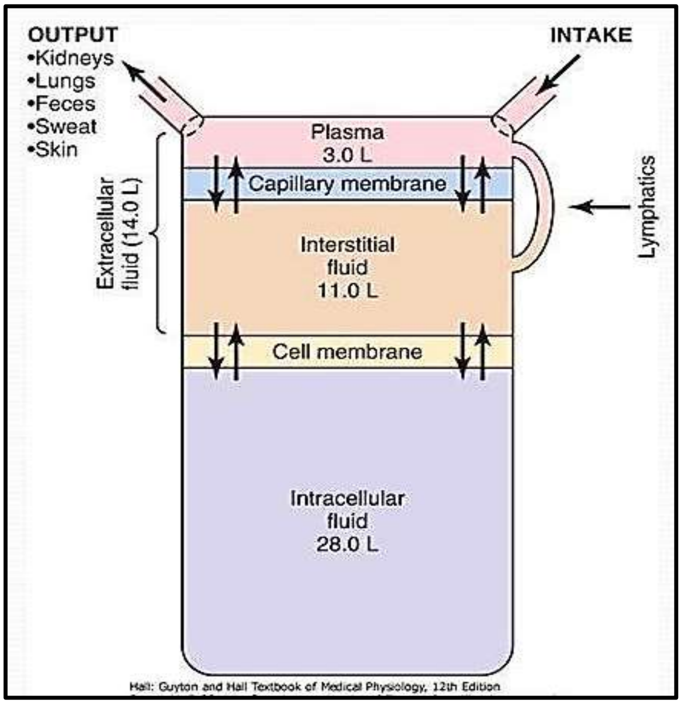
  Multiple mechanisms control the rate of urine excretion. In fact, the most important means by which the body maintains a balance between water intake and output, as well as a balance between intake and output of most electrolytes in the body, is by controlling the rates at which the kidneys excrete these substances. For example, urine volume can be as low as 0.5 L/day in a dehydrated person or as high as 20 L/day in a person who has been drinking remarkable amounts of water.

Body fluid compartments

The total body water or body fluid represents approximately 60% (42 L) of the body weight of a person. It is distributed mainly between two compartments:

1. Extracellular fluid (ECF) forming 20% of the total body weight (14 L).
    a. Plasma (intravascular fluid).
    b. Interstitial fluid.
    c. Other Fluids: transcellular fluid.
2. Intracellular fluid (ICF) forming 40 % of the total body weight (28L).





In human beings, the total body water varies from **(45-75) %** of body weight. In a 70-kg adult man, the total body water is about (60- 65) % of the body weight, or about 42 liters. This percentage depends on **age**, **gender**, and **degree of obesity** (percentage of body fat). As a person grows older, the percentage of total fluid gradually decreases. This decrease is due in part to the fact that aging is usually associated with an increased percentage of the body weight being fat, which decreases the percentage of water in the body.

Because women normally have a greater percentage of body fat compared with men, their total body water averages about (50- 55) % of the body weight. In premature and newborn babies, the total body water ranges from (70- 75) % of body weight.

Intracellular fluid compartment

About 28 of the 42 liters of fluid in the body are inside the cells and are collectively called the intracellular fluid. Thus, the intracellular fluid constitutes about 40% of the total body weight in an "average" person.

The fluid of each cell contains its individual mixture of different constituents, but the concentrations of these substances are similar from one cell to another. In fact, the composition of cell fluids is remarkably similar even in different animals, ranging from the most primitive microorganisms to humans.

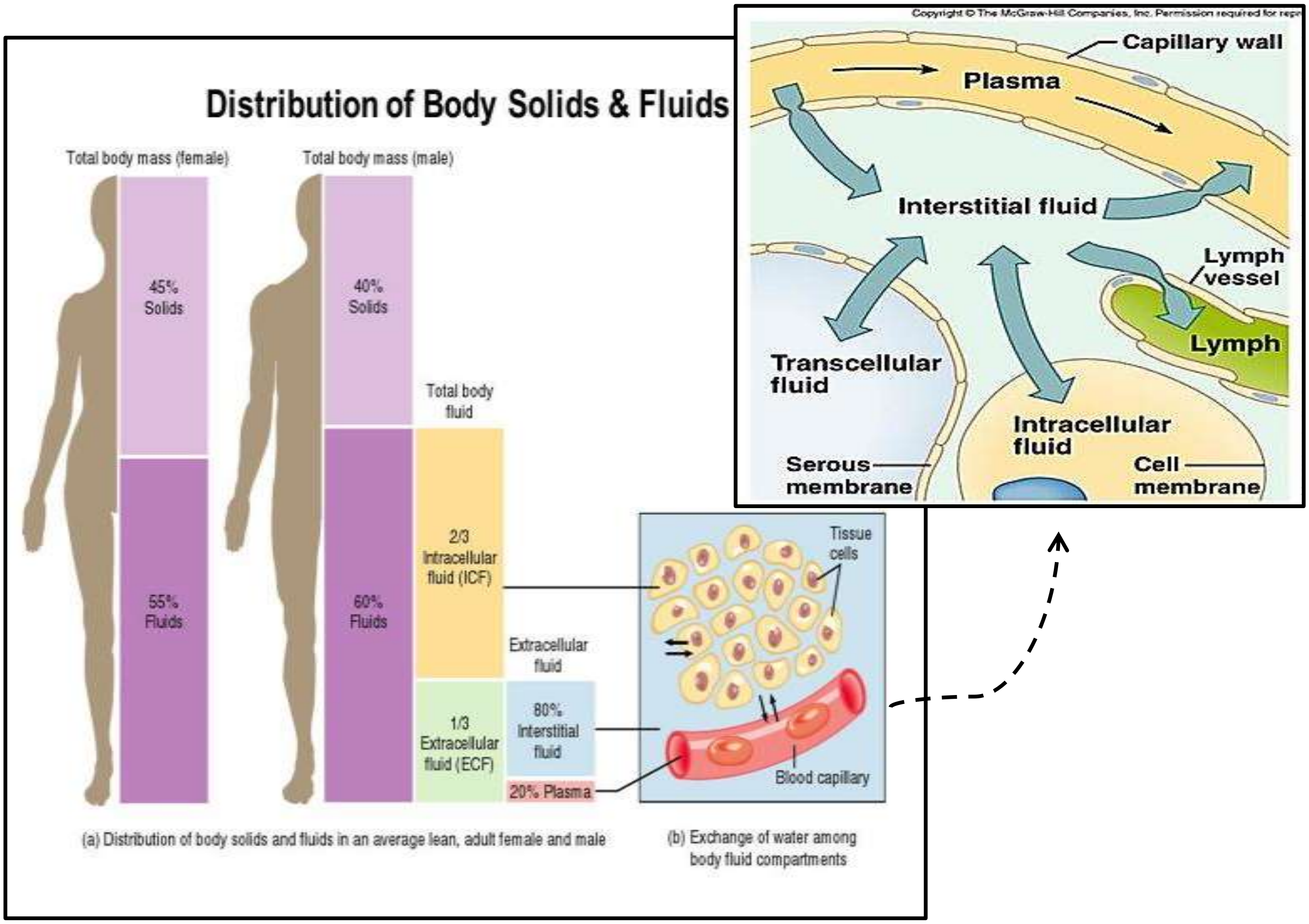
Extracellular fluid compartment

All the fluids outside the cells are collectively called the extracellular fluid. Together these fluids account 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:

1- **The interstitial fluid**, which makes up more than three fourths (3/4) or (11 liters) of the extracellular fluid.

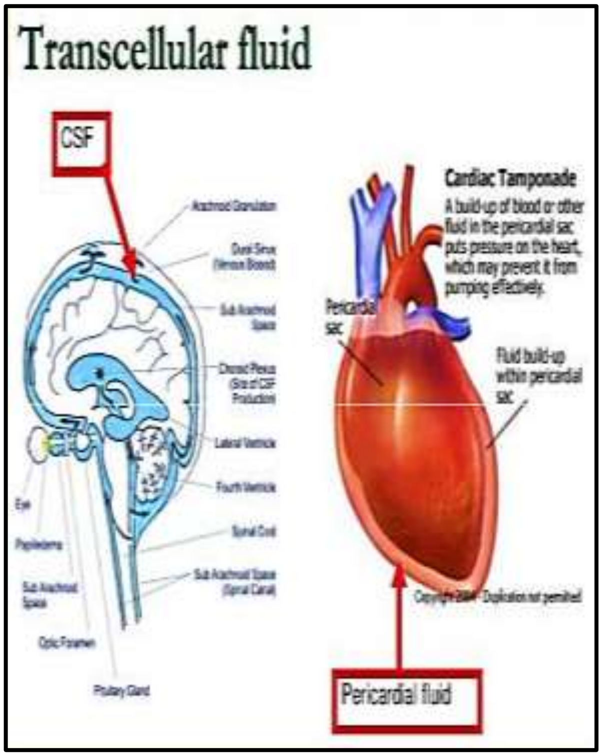
2- **The plasma**, which makes up almost one fourth (1/4) of the extracellular fluid, or about 3 liters. The plasma is the non-cellular part of the blood; it exchanges substances continuously with the interstitial fluid through the pores of the capillary membranes. These pores are highly permeable to almost all solutes in the extracellular fluid except the proteins.

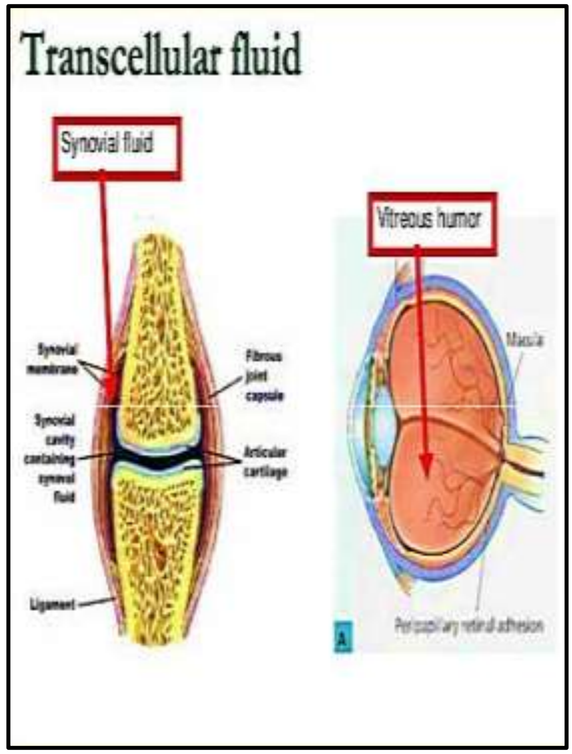
Therefore, the plasma and interstitial fluids have about the same composition except for proteins, which have a higher concentration in the plasma.



Also, there is small compartment of extracellular fluid that is referred to as **transcellular fluid,** found in the cavities separated from other extracellular fluids by epithelial or connective tissue membranes, (constitute about 1-2 liters). Transcellular fluid includes fluid in:

1- The synovial.
2- Peritoneal.
3- Pericardial.
4- Intraocular spaces, as well as,
5- The cerebrospinal fluid (CSF); it is usually considered to be a specialized type of extracellular fluid, although in some cases its composition may differ markedly from that of the plasma or interstitial fluid.





Constituents of extracellular and intracellular fluids

Extracellular fluid constituents

Ionic composition of plasma and interstitial fluid is similar, because the plasma and interstitial fluid are separated only by highly permeable capillary membranes. The most important difference between these two compartments is the higher concentration of protein in the plasma; because the capillaries have a low permeability to the plasma proteins, only small amounts of proteins are leaked into the interstitial spaces.

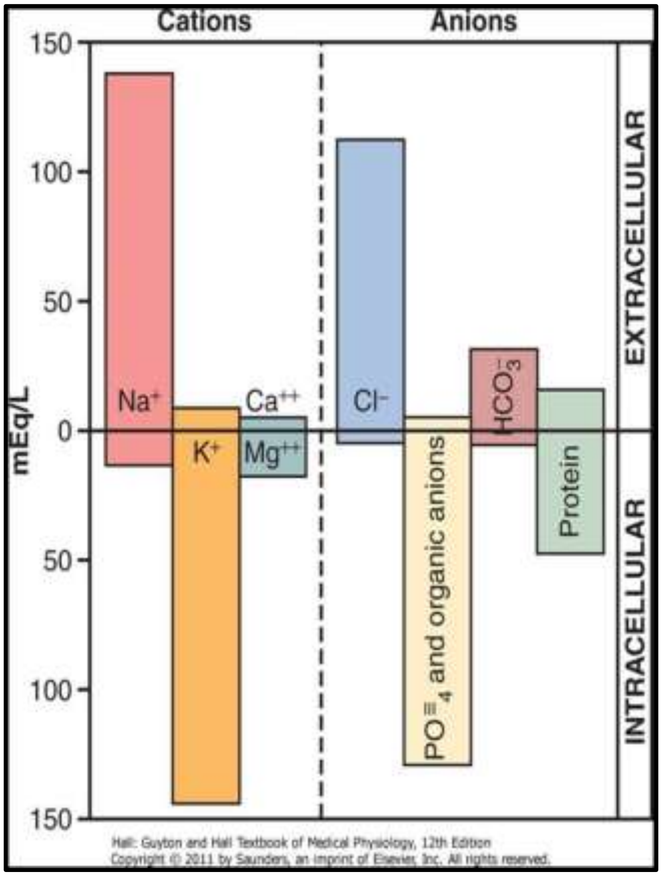
The extracellular fluid, including the plasma and the interstitial fluid, contains large amounts of sodium (Na^+) and chloride ions (Cl^-), reasonably large amounts of bicarbonate ions ($HCO3^-$), but only small quantities of potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), phosphate, (Po_4^{-3}) and organic acid ions. The composition of extracellular fluid is carefully regulated by various mechanisms, but especially by the kidneys. This regulation allows the cells to remain continually bathed in a fluid that contains the proper concentration of electrolytes and nutrients for optimal cell function.

Intracellular fluid constituents

The intracellular fluid is separated from the extracellular fluid by a cell membrane that is highly permeable to water but is not permeable to most of the electrolytes in the body.

In contrast to the extracellular fluid, the intracellular fluid contains only small quantities of Na^+ and Cl^- ions and almost no Ca^{++} ions. Instead, it contains large amounts of K^+ and Po_4^{-3} ions plus moderate quantities of Mg^{++} and So_4^{-2} ions, all of which have low concentrations in the extracellular fluid. Also, cells contain large amounts of protein- almost 4 times as much as in the plasma.

Intracellular Fluid	**Extracellular Fluid**
Major Cations	**Major Cations**
Potassium (K^+)	Sodium (Na^+)
Magnesium (Mg^{++})	Potassium (K^+)
Sodium (Na^+)	Magnesium (Mg^{++})
	Calcium (Ca^{++})
Major Anions	**Major Anions**
Phosphate (Po_4^{-3})	Chloride (Cl^-)
Chloride (Cl^-)	Bicarbonate (HCO_3^-)
Bicarbonate (HCO_3^-)	Phosphate (Po_4^{-3})
Sulfate (So_4^{-2})	



Most body fluids are neutral in charge. Thus, cations, or positively charged ions, and anions, or negatively charged ions, are balanced in fluids. As seen in the previous graph, Na^+ ions and Cl^- ions are concentrated in the ECF of the body, whereas K^+ ions are concentrated inside cells.

Although Na^+ and K^+ can “leak” through “pores” into and out of cells, respectively, the high levels of K^+ and low levels of Na^+ in the ICF are maintained by Na^+-K^+ pumps in the cell membranes. These pumps use the energy supplied by ATP to pump sodium out of the cell and potassium into the cell.

Two major factors contribute to the movement of fluid from one compartment to another: 1- hydrostatic pressure, and 2- osmotic pressure

Hydrostatic pressure

The pressure (or force) exerted by a fluid against a wall at equilibrium, at a given point within the fluid, due to the force of gravity causes movement of fluid between compartments. Hydrostatic pressure increases in proportion to depth measured from the surface because of the increasing weight of fluid exerting downward force from above.
The hydrostatic pressure of blood is the pressure exerted by blood against the walls of the blood vessels by the pumping action of the heart.

Osmotic pressure

Osmotic pressure is the minimum pressure which needs to be applied to a solution to prevent the inward flow of its pure solvent across a semipermeable membrane. It is also defined as the measure of the tendency of a solution to take in pure fluid by osmosis.
For example, in blood vessels, fluids leave the plasma at the arteriolar ends of capillaries and enter the interstitial spaces because of the net outward force of hydrostatic pressure (blood pressure). Fluid returns to the plasma from the interstitial spaces at the venular ends of capillaries because of the net inward force of colloid osmotic pressure due to the plasma proteins. Likewise, tissue fluid and lymph, fluid leaves the interstitial spaces and enters the lymph capillaries due to the hydrostatic pressure of the interstitial fluid. Hydrostatic pressure in the cells and surrounding interstitial fluid is ordinarily equal and remains stable. Therefore, any net fluid movement is likely to be the result of changes in osmotic pressure.

Basic principles of osmosis and osmotic pressure

Because cell membranes are relatively impermeable to most solutes but are highly permeable to water (i.e., they are selectively permeable), 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. The rate of diffusion of water is called the rate of osmosis.

Osmolality and Osmolarity

Osmolality when the concentration of a solution is expressed as osmoles per kilogram of water; it is called **osmolarity** when it is expressed as osmoles per liter of solution. In dilute solutions such as the body fluids, these two terms can be used almost synonymously because the differences are small.

In most cases, it is easier to express body fluid quantities in liters of fluid rather than in kilograms of water. Therefore, most of the calculations used clinically and the calculations are based on osmolarities rather than osmolalities.