2nd Lecture
General Idea about Body fluids: Types, Composition, and Functions, Measurement of body fluids

The maintenance of a relatively constant volume and a stable composition of the body fluids is essential for homeostasis. Some of the most common and important problems in clinical medicine arise because of abnormalities in the control systems that maintain this constancy of the body fluids.

Fluid Intake and Output Are Balanced During Steady-State Conditions:

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 compartments of the body. For example, there is a highly variable fluid intake that must be carefully matched by equal output of water from the body to prevent body fluid volumes from increasing or decreasing.

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 the food, which together normally add about 2100ml/day to the body fluids, and (2) it is synthesized in the body as a result of oxidation of carbohydrates, adding about 200ml/day. This provides a total water intake of about 2300ml/day (Table 25-1). Intake of water, however, 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 of the water losses cannot be precisely regulated. For example, there is a continuous loss of water by evaporation from the respiratory tract and diffusion through the skin, which together account for about 700ml/day of water loss under normal conditions. This is termed insensible water loss because we are not consciously aware of it, even though it occurs continually in all living humans. The 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 to

400ml/day. This loss is minimized by the cholesterol-filled cornified layer of the skin, which provides a barrier against excessive loss by diffusion. When the cornified layer becomes denuded, as occurs with extensive burns, the rate of evaporation can increase as much as 10-fold, to 3 to 5L/day. For this reason, burn victims must be given large amounts of fluid, usually intravenously, to balance fluid loss. Insensible water loss through the respiratory tract averages about 300 to 400ml/day. As air enters the respiratory tract, it becomes saturated with moisture, to a vapor pressure of about 47mm Hg, before it is expelled. Because the vapor pressure of the inspired air is usually less than 47mm Hg, water is continuously lost through the lungs with respiration. In cold weather, the atmospheric vapor pressure decreases to nearly 0, causing an even greater loss of water from the lungs as the temperature decreases. This explains the dry feeling in the respiratory passages in cold weather.

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 100ml/day, but in very hot weather or during heavy exercise water loss in sweat occasionally increases to 1 to 2L/hour.

Water Loss in Feces. Only a small amount of water (100ml/day) normally is lost in the feces. This can increase to several liters a day in people with severe diarrhea. For this reason, severe diarrhea can be life threatening if not corrected within a few days.

Water Loss by the Kidneys. The remaining water loss from the body occurs in the urine excreted by the kidneys. There are multiple mechanisms that 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 0.5L/day in a dehydrated person or as high as 20L/day in a person who has been drinking tremendous amounts of water.

Table 1: Daily Intake and Output of Water (ml/day)

	Normal	Prolonged, Heavy Exercise
Intake		
Fluids ingested	2100	?
From metabolism	200	200
Total intake	2300	?
Output		
Insensible—skin	350	350
Insensible—lungs	350	650
Sweat	100	5000
Feces	100	100
Urine	1400	500
Total output	2300	6600

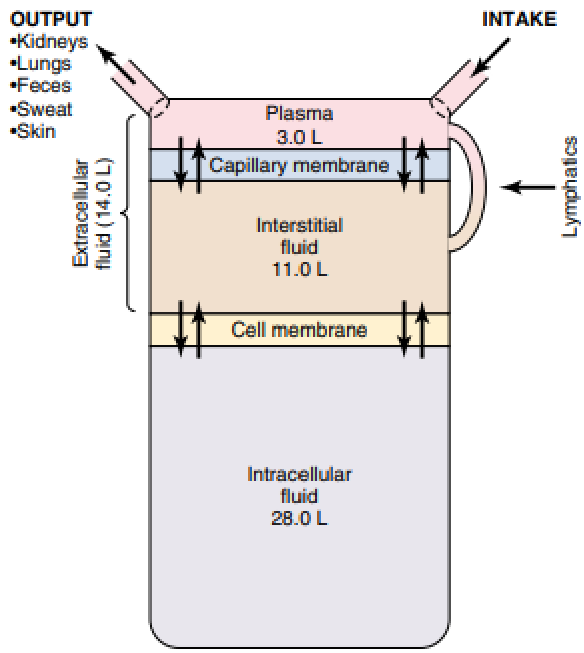

Figure1 : Summary of body fluid regulation, including the major body fluid compartments and the membranes that separate these compartments. The values shown are for an average 70-kilogram person

Body Fluid Compartments:

The total body fluid is distributed mainly between two compartments: the extracellular fluid and the intracellular fluid (Figure1). The extracellular fluid is divided into the interstitial fluid and the blood plasma. There is another small compartment of fluid that is referred to as transcellular fluid. This compartment includes fluid in the synovial, peritoneal, pericardial, and intraocular spaces, as well as the cerebrospinal fluid; 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. All the transcellular fluids together constitute about 1 to 2 liters. In the average 70-kilogram adult man, the total body water is about 60 percent of the body weight, or about 42 liters. This percentage can change, depending on age, gender, and degree of obesity. As a person grows older, the percentage of total body weight that is fluid gradually decreases. This 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 more body fat than men, their total body water averages about 50 percent of the body weight. In premature and newborn babies, the total body water ranges from 70 to 75 percent of body weight.

Intracellular Fluid Compartment:

About 28 of the 42 liters of fluid in the body are inside the 100 trillion cells and are collectively called the intracellular fluid. Thus, the intracellular fluid constitutes about 40 percent 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. For this reason, the intracellular fluid of all the different cells together is considered to be one large fluid compartment.

Extracellular Fluid Compartment:

All the fluids outside the cells are collectively called the extracellular fluid. Together these fluids account for about 20 percent of the body weight, or about 14 liters in a normal 70-kilogram man. The two largest compartments of the extracellular fluid are the interstitial fluid, which makes up more than three fourths (11 liters) 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; 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 constantly mixing, so the plasma and interstitial fluids have about the same composition except for proteins, which have a higher concentration in plasma.

Blood Volume:

Blood contains both extracellular fluid (the fluid in plasma) and intracellular fluid (the fluid in the red blood cells). However, blood is considered to be a separate fluid compartment because it is contained in a chamber of its own, the circulatory system. The blood volume is especially important in the control of cardiovascular dynamics. The average blood volume of adults is about 7 percent of body weight, or about 5 liters. About 60 percent of the blood is plasma and 40 percent is red blood cells, but these percentages can vary considerably in different people, depending on gender, weight, and other factors.

Constituents of Extracellular and Intracellular Fluids:

Comparisons of the composition of the extracellular fluid, including the plasma and interstitial fluid, and the intracellular fluid are shown in Figures 2 and 3 and in Table 2. Ionic Composition of Plasma and Interstitial Fluid Is Similar Because the plasma and interstitial fluid are separated only by highly permeable capillary membranes, their ionic composition is similar. 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 in most tissues. The plasma proteins have a net negative charge and, therefore, tend to bind cations, such as sodium and potassium ions, thus holding extra amounts of these cations in the plasma along with the plasma proteins. Conversely, negatively charged ions (anions) tend to have a slightly higher concentration in the interstitial fluid compared with the plasma, because the negative charges of the plasma proteins repel the negatively charged anions. For practical purposes, however, the concentration of ions in the interstitial fluid and in the plasma is considered to be about equal. Referring again to Figure 2, one can see that 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. The composition of extracellular fluid is carefully regulated by various mechanisms, but especially by the kidneys, as discussed later. This 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 not to most of the electrolytes in the body. In contrast to the extracellular fluid, 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, all of which have low concentrations in the extracellular fluid. Also, cells contain large amounts of protein, almost four times as much as in the plasma.

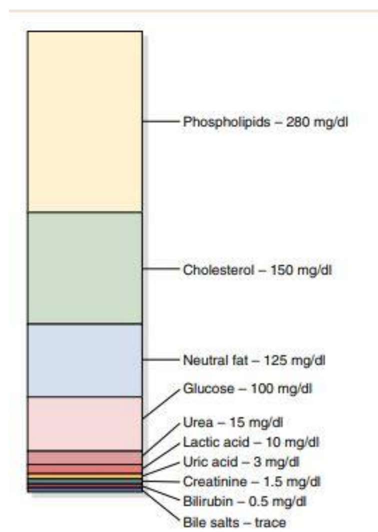

Figure 3: Nonelectrolytes of the plasma.

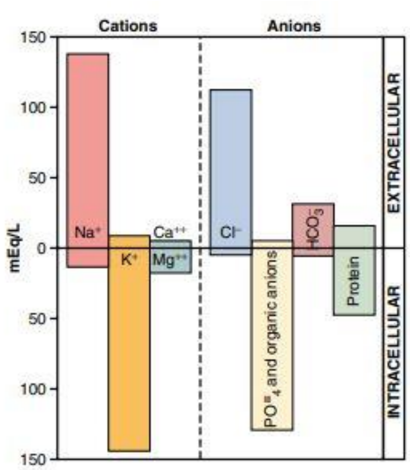

Figure 4 :Major cations and anions of the intracellular and extracellular fluids. The concentrations of Ca++ and Mg++ represent the sum of these two ions. The concentrations shown represent the total of free ions and complexed ions.

Table 2: Osmolar Substances in Extracellular and Intracellular Fluids

	Plasma (mOsm/L H_2O)	Interstitial (mOsm/L H_2O)	Intracellular (mOsm/L H_2O)
Na^+	142	139	14
K^+	4.2	4.0	140
Ca^{++}	1.3	1.2	0
Mg^{++}	0.8	0.7	20
Cl^-	108	108	4
HCO_3^-	24	28.3	10
$HPO_4^=$, $H_2PO_4^-$	2	2	11
$SO_4^=$	0.5	0.5	1
Phosphocreatine			45
Carnosine			14
Amino acids	2	2	8
Creatine	0.2	0.2	9
Lactate	1.2	1.2	1.5
Adenosine triphosphate			5
Hexose monophosphate			3.7
Glucose	5.6	5.6	
Protein	1.2	0.2	4
Urea	4	4	4
Others	4.8	3.9	10
Total mOsm/L	301.8	300.8	301.2
Corrected osmolar activity (mOsm/L)	282.0	281.0	281.0
Total osmotic pressure at 37 °C (mm Hg)	5443	5423	5423

Body water or fluid functions

Our bodies contain a lot of water 60% of an adult's weight In other words, the body of a 70 kg man contains about 42 liters of water. Water is essential for physiological processes of digestion, absorption and excretion. A loss of 20% of body water may cause death; loss of only 10% causes severe disorders. In moderate weather, adults can live up to 10 days without water, and children can live up to 5 days. In contrast, it is possible to survive for several weeks without food. So functions of water are:

1. Acts as medium for various physical processes, for example: diffusion, osmosis and filtration.

2. An essential constituent of all living cells.

3. Solvent action. It provides a medium for all chemical and enzymatic reactions.

4. plays an important role in regulation the pH and osmotic pressure of various body fluid.

5. Essential for gases exchange of oxygen and carbon dioxides in the tissue and lungs.

6.Regulates the body temperature through its properties of heat absorption and distribution**.**

7.It exerts a lubricant action in potential spaces. For example; joints, pleura and pericardium.
8. Major component of blood plasma.
9.It acts as a vehicle for various physiological processes, for example; absorption of different foods tufts form GIT and reabsorption of various substances from renal tubule.
10. In cerebrospinal fluid, it acts as mechanical buffer which prevents injury of the brain and in the eye, it acts as a refractive medium for light rays.

The measurement of body fluids

The measurement of body fluids involves determining the volumes of different fluid compartments within the body using various techniques and indicators. Here is a summary of the methods and measurements:

Fluid Compartments and Their Measurements

1. Total Body Water (TBW)

Percentage of Body Weight: Approximately 60% in adult men and slightly lower in women.

Measurement Method: Usually measured using isotopes like tritium oxide (THO) or deuterium oxide (D_2O) due to their ability to distribute evenly throughout all body water compartments.

2. Intracellular Fluid (ICF)

Percentage of TBW: Accounts for about 40% of total body weight.

Measurement Method: ICF volume is not measured directly but calculated as the difference between total body water and extracellular fluid volume.

3. Extracellular Fluid (ECF)

Percentage of TBW: Comprises about 20% of total body weight.

Measurement Method: Measured using substances like inulin, mannitol, or radioisotopes such as 22Na. These indicators are chosen for their ability to remain primarily in the extracellular space.

4. Plasma Volume

Percentage of Body Weight: Approximately 5% of total body weight.

Measurement Method: Commonly measured using Evans' blue dye or radio-labeled albumin, which binds to plasma proteins.

5. Interstitial Fluid

Percentage of ECF: Makes up about 15% of total body weight.

Measurement Method: Calculated indirectly as the difference between ECF volume and plasma volume.

Table 3: Measurement of Body Fluid Volumes

Volume	Indicators
Total body water	$^{3}H_2O$, $^{2}H_2O$, antipyrine
Extracellular fluid	^{22}Na, ^{125}I-iothalamate, thiosulfate, inulin
Intracellular fluid	(Calculated as total body water − extracellular fluid volume)
Plasma volume	^{125}I-albumin, Evans blue dye (T-1824)
Blood volume	^{51}Cr-labeled red blood cells, or calculated as blood volume = plasma volume/(1 − hematocrit)
Interstitial fluid	(Calculated as extracellular fluid volume − plasma volume)

Reference:

13TH EDITION Guyton and Hall Textbook of Medical Physiology pp305-309

https://derangedphysiology.com/main/cicm-primary-exam/required-reading/body-fluids-and-electrolytes/Chapter%20016/measuring-volume-body-fluid-compartments