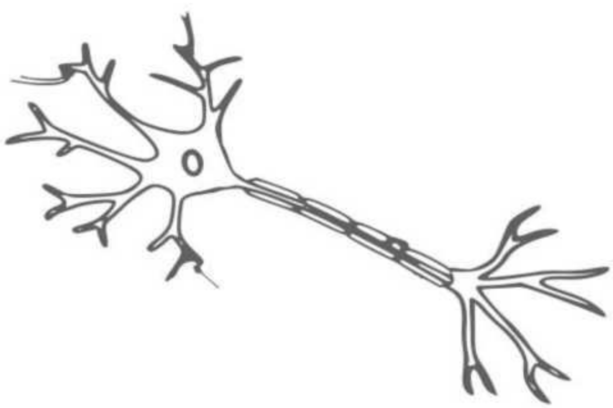
Sheet no 15

Physiology



Writer: AHMAD ALLAHAM

Corrector: Nermeen abu halaweh

Doctor: MOHAMMAD KATATBEH

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 relative constancy of the body fluids.

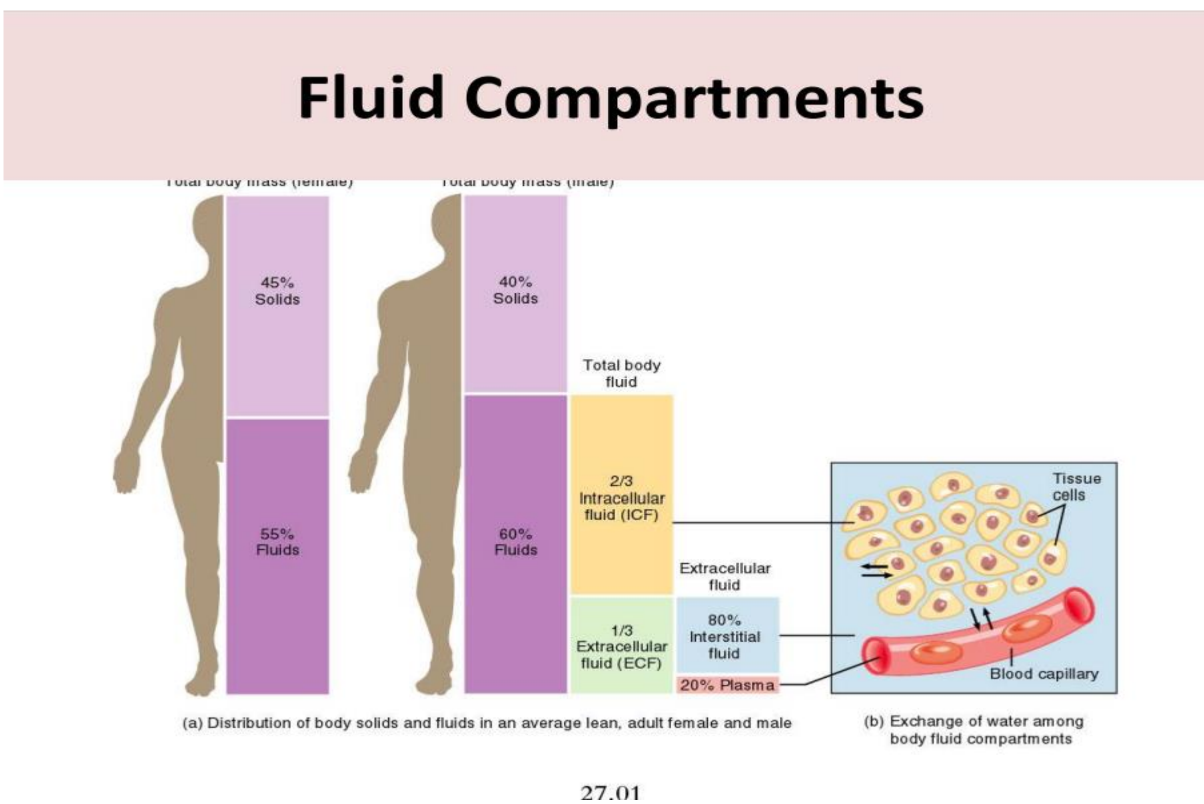
-Water is forming around 60% of the total body mass in males and around 52-55% of the total body mass in females (the difference in percentage is because females have more fats than males).

These fluids are distributed inside cells and outside cells forming 2 compartments: 1) 2/3 of these fluids are found inside cells forming intracellular fluid compartment.

2) 1/3 of these fluids are distributed outside cells forming extracellular fluid compartment (ECF):

A- 80% of (ECF) are found between cells forming interstitial fluid.

B- around 20% of (ECF) are found inside vessels forming plasma (which is around the red blood cells and the blood cells inside vessels).



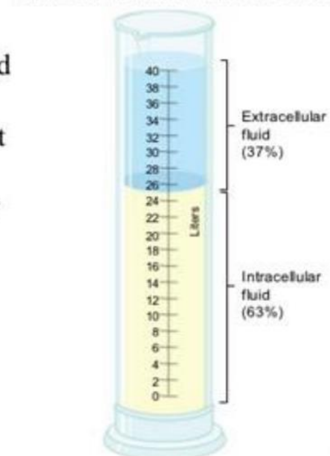
Extracellular fluid can be:
A. plasma.
B. lymph (in lymphatic vessels).
C. small amount transcellular fluid (in certain cavities in our body).

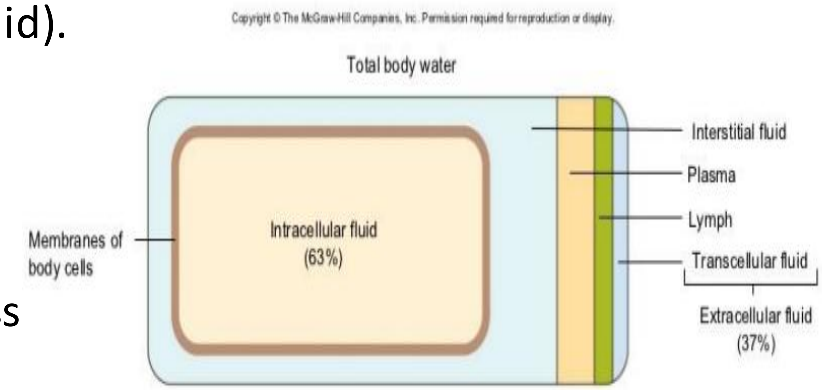
-Transcellular fluid can be found in:
- Synovial fluid (Joints).
- Pericardial fluid (around the heart).
- Pleural fluid (around the lungs).
- Peritoneal fluid (gastrointestinal fluid).
- Ocular fluid (in the eye).
- Cerebrospinal fluid (around neural tissue in CNS).

-> the difference between males and females is attributed with the fat mass that is found in female.

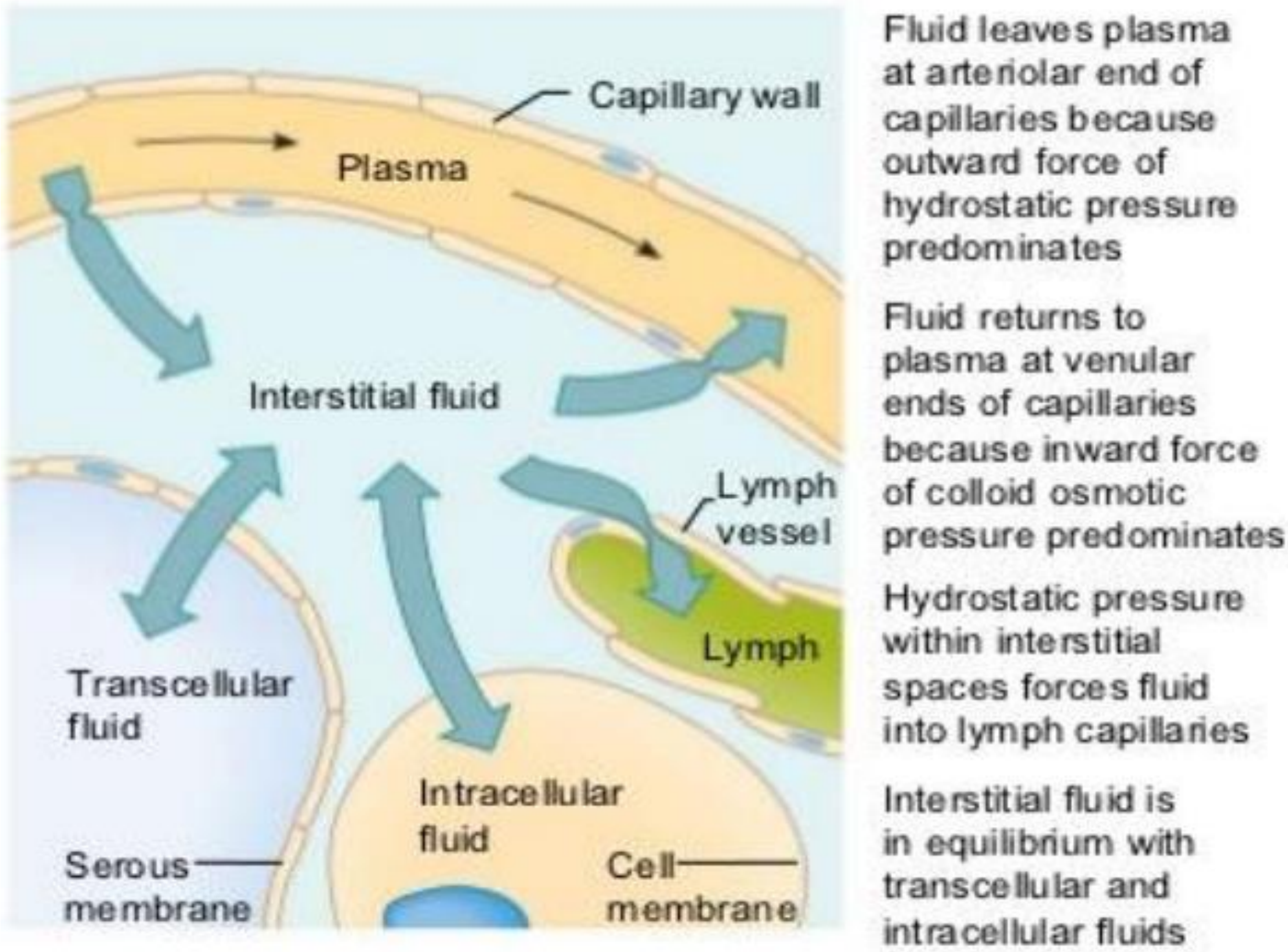
-notes form the book: transcelluar fluid usually is considered to be a specialized type of extracellular fluid, although in some cases its composition may differ markedly from that of the plasma or interstitial fluid. All the transcellular fluids together constitute about 1 to 2 liters.
The intracellular 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.

- Of the 40 liters of water in the body of an average adult, about two-thirds is intracellular fluid and one-third is extracellular fluid
- An average adult female is about 52% water by weight, and an average male about 63% water by weight





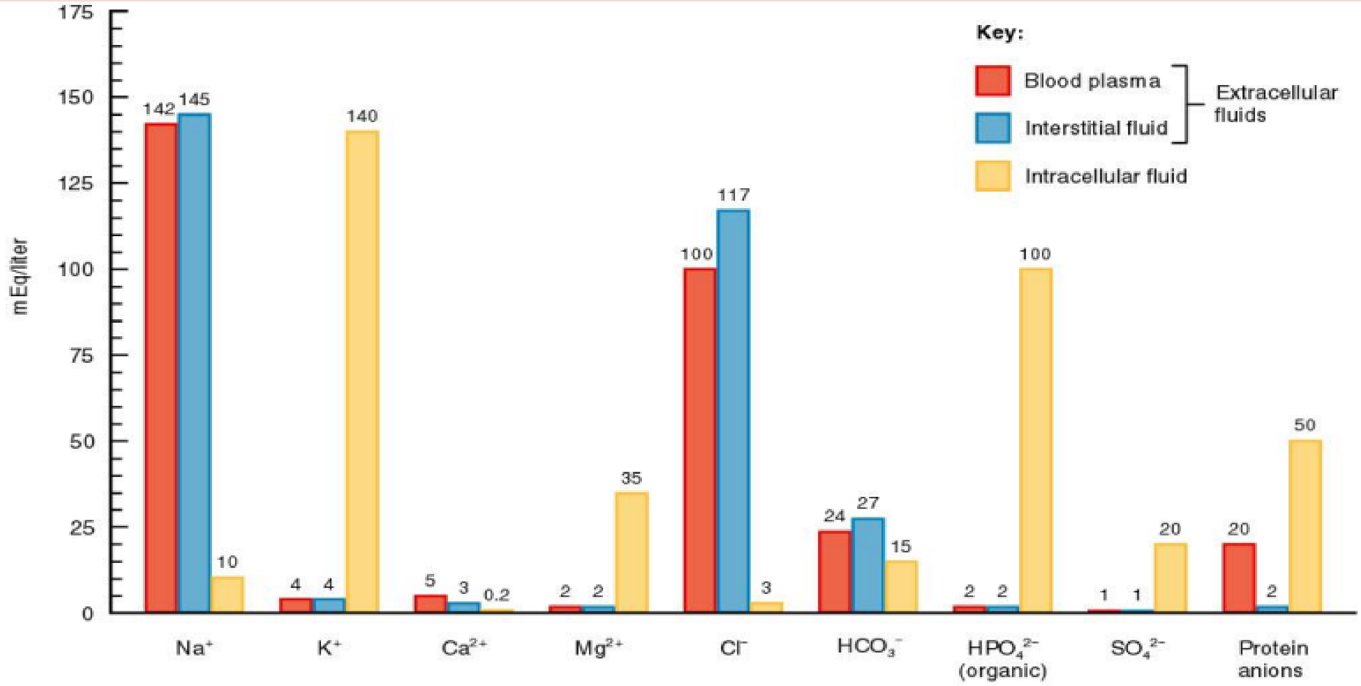
-Movement of Fluids between compartments
These fluids that are found inside body are not static all the time we have exchange between different compartments (as arrows) the movement of fluid is regulated by certain factors as:
1- osmotic pressure(affected by osmolarity).
2- hydrostatic pressure(related to the volume of ECF).



water moves between these compartments according to the pressure we are having in these compartments; the composition of these fluid may vary according to compartments (example: Na^+ in extracellular compartment is high while K^+ in intracellular fluid is high and we have low K^+ in ECF)

Remember that
-Osmotic pressure is a pulling force that results from the osmotically active particels.
-While hydrostatic pressure is a pushing force results from the difference in water height in the two columns.

Composition of Body Fluids



-There are also differences between sub compartments (example: higher amount of protein in plasma than in interstitial fluid both belong to ECF).

Water Balance

Water input = Water output.

Water is always balanced so whenever there is an increase in water output There will be an increase in water input and vice versa other wise this will lead to diseases if it was not balanced.

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

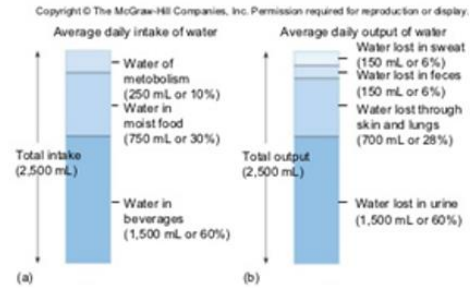
Now let’s talk about water input:
The volume of water gained daily varies among individuals, averaging about 2500 mL/day (2.5 liters/day).

a. 60% Drinking.

b. 30% moist food (ingested food).

c. 10% Metabolic processes in the body after oxidative phosphorylation (the final degradation of nutrients resulting of water and CO_2).

- The volume of water gained each day varies among individuals averaging about 2,500 milliliters daily for an adult:
  - 60% from drinking
  - 30% from moist foods
  - 10% as a bi-product of oxidative metabolism of nutrients called water of metabolism



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 add about 2100 ml/day to the body fluids, and

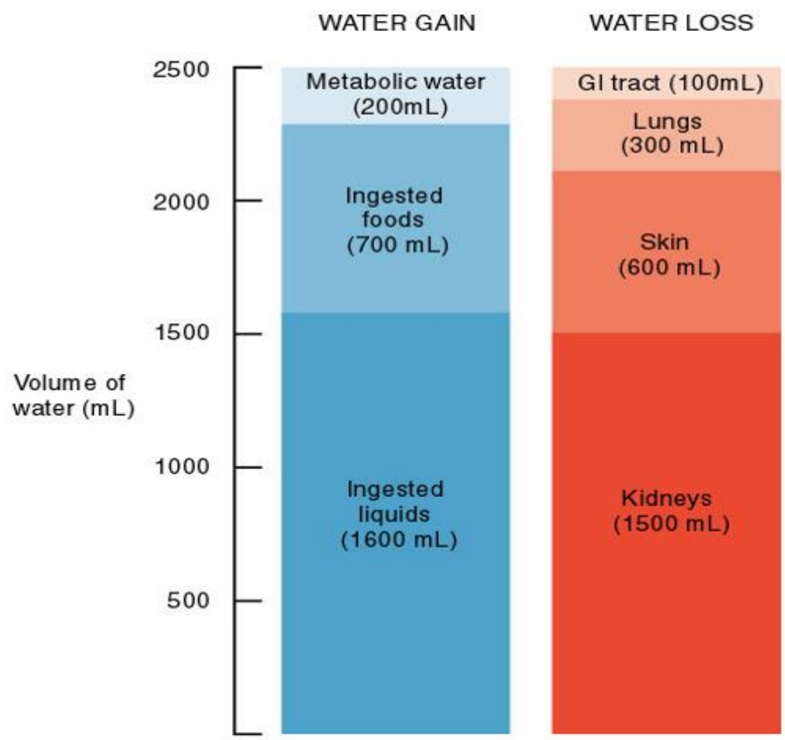
(2) it is synthesized in the body by oxidation of carbohydrates, adding about 200 ml/day. These mechanisms provide a total water intake of about 2300 ml/day .However, intake of water is highly variable among different people and even within the same person on different days, depending on climate, habits, and level of physical activity.

Water output--------->

- Water normally enters the body only through the mouth, but it can be lost by a variety of routes including:
  - Urine (60% loss)
  - Feces (6% loss)
  - Sweat (sensible perspiration) (6% loss)
  - Evaporation from the skin (insensible perspiration)
  - The lungs during breathing

  (Evaporation from the skin and the lungs is a 28% loss)

Notes you need to know my fellows:
Water can be lost from our bodies in a insensible way and in a sensible way
But what do we mean by that??
Insensible simply you don't feel it or sense it such as the continuous loss of water by evaporation from the respiratory tract and diffusion through the skin and it is termed insensible because we are not consciously(واعي) aware of it, even though it occurs continually in all living humans.



While on the other hand sensible water loss we are aware of it such as urination it can be perceived by the senses and can be measured. If you've **lost** it, you know you've **lost** it!
But insensible is usually hard to measure and you are not aware of the loss.

Okay now the real question is how can we keep the homeostasis of fluids in our bodies and what are the systems involved in this life preserving process???

we should conclude that water balance is highly regulated in our bodies. There are many systems that are involved in the regulation of water's amount in our bodies and the regulation of fluids and electrolytes, like:
-Urinary system
-Cardiovascular system
-Endocrine system, through (Pituitary, parathyroid and adrenal glands)
-Respiratory system (Lungs participate in this process of regulation).
Fluids in our bodies are not static, rather they are Dynamic. That's why you always have movement of fluids between interstitial fluid and other fluids (intracellular fluid, transcellular fluid, plasma and lymph fluid).
The regulation of fluids and electrolytes in our bodies leads to Homeostasis

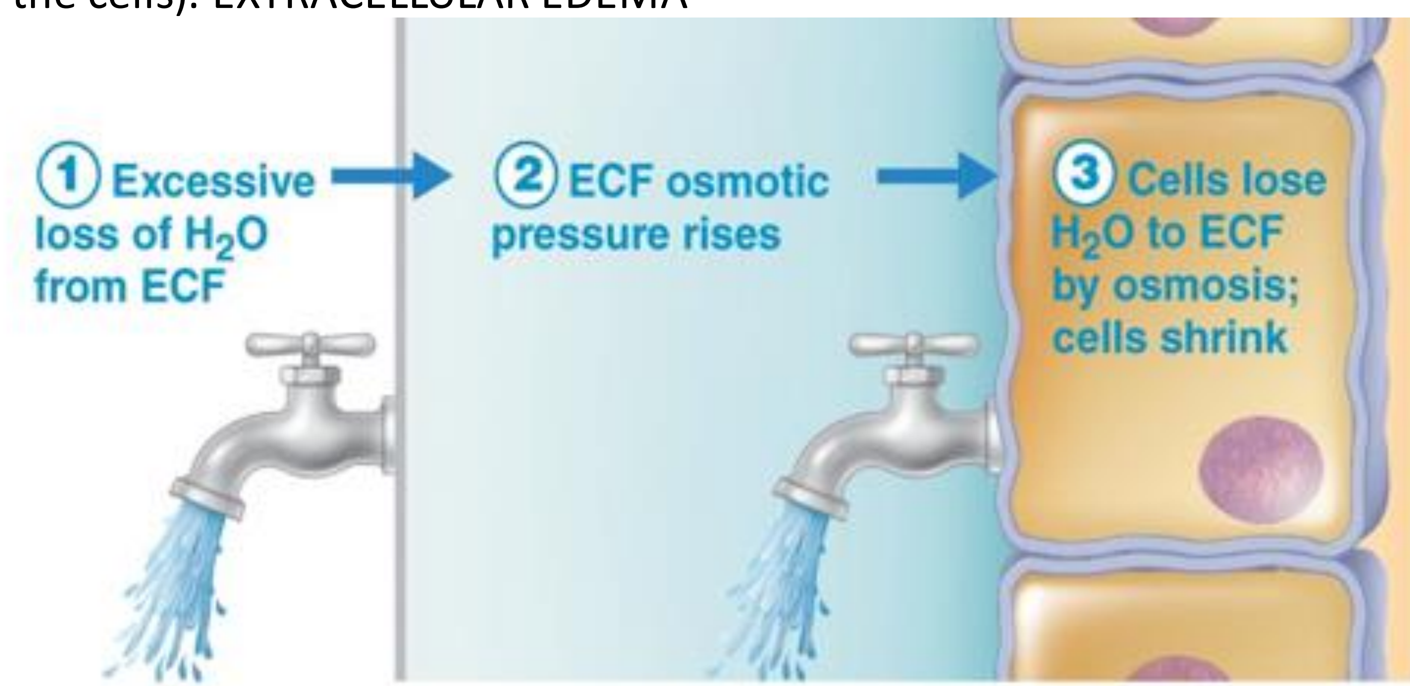
Regulation of Na+ and Water

Involves regulation of:

- Osmolality
- Volume of ECF

different regulations with many overlapping mechanisms.

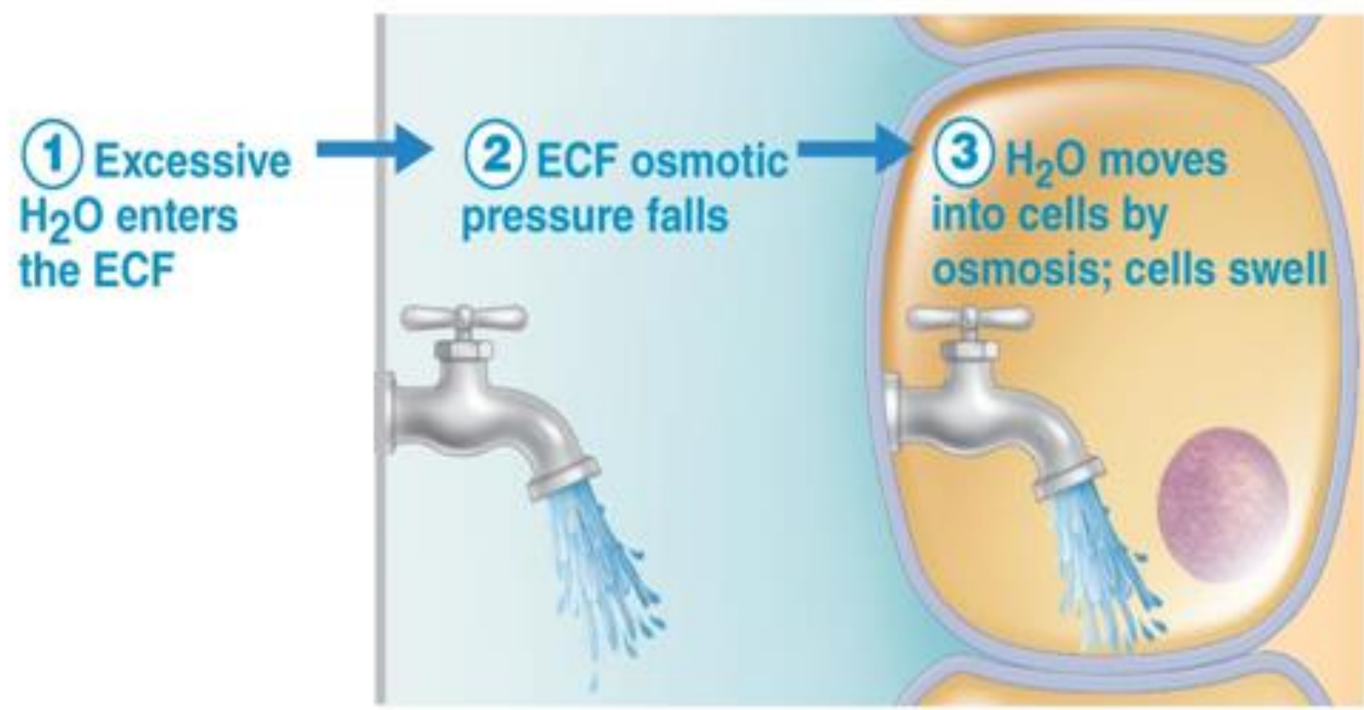
Now we shall talk about the regulation of Na+ and water but before that … you should know that there is an overlapping in the mechanisms involved in the regulation of water and Na+:
What is the importance of na and water regulation?
To answer this question, imagine that we have excessive loss of water from the body (water without Na+). In this case, ECF volume will decrease, so the osmolarity of the ECF will increase and this will cause water to move from inside the cells towards ECF and this will end with shrinkage of cells.
This process is called Dehydration of cells (we are decreasing the volume of water inside the cells). EXTRACELLULAR EDEMA



(a) Consequences of dehydration. If more water than solutes is lost, cells shrink.

What will happen if we have excessive intake of water? Surely, you will say that ECF volume will increase and the osmolarity of ECF will decrease. As a result, water will move from ECF towards cells. This will end with swelling of cells. This is important for you as a doctor, because when this happens in some tissues and organs, it leads to intracellular edema.

Info from the book about edema and I will leave to you some notes from the book in the last page of this sheet:
Edema refers to the presence of excess fluid in the body tissues. In most instances, edema occurs mainly in the extracellular fluid compartment, but it can involve intracellular fluid as well.

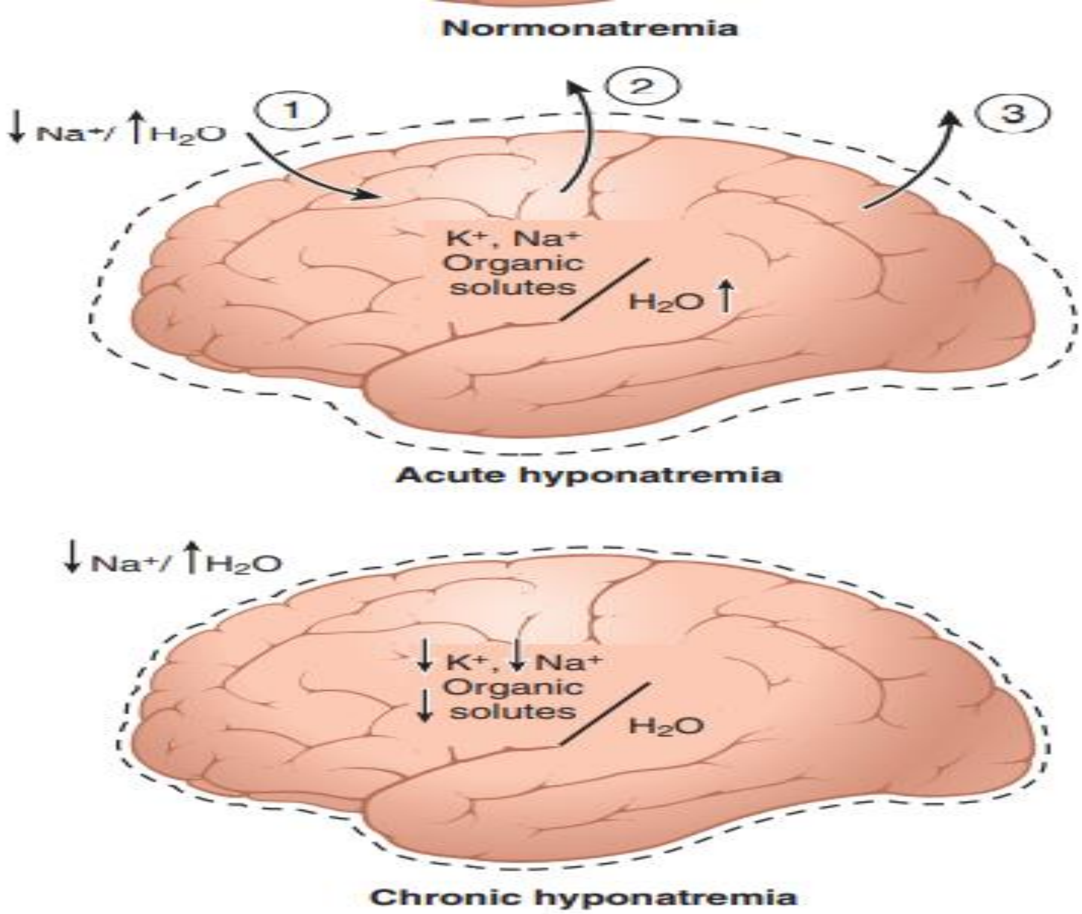


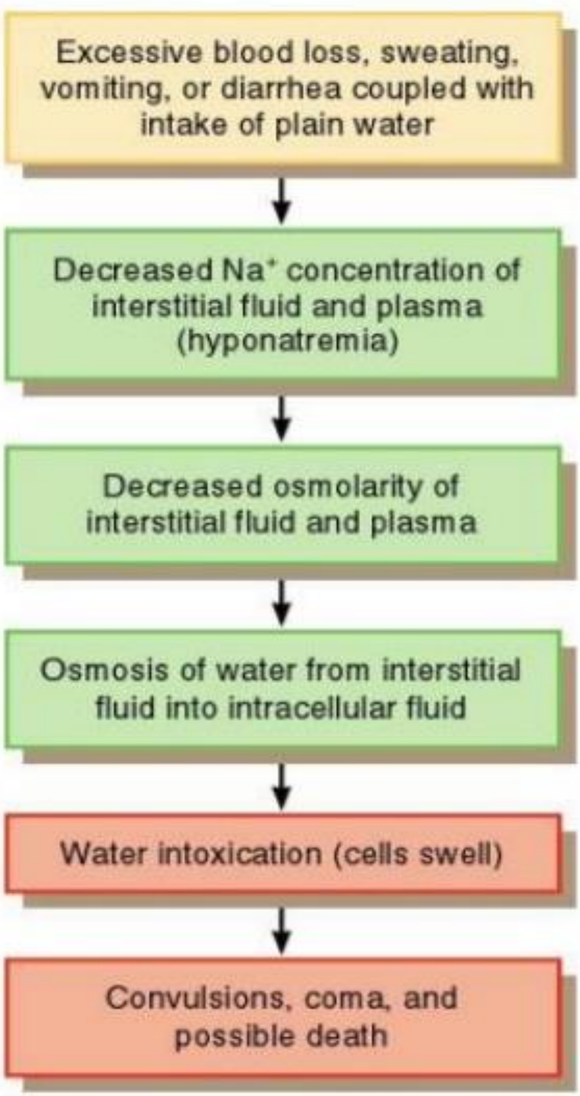
(b) Consequences of hypotonic hydration (water gain).
If more water than solutes is gained, cells swell.

You should know that neither dehydration nor swelling is healthy.
EXAMPLE:
To deeply understand the following example, you have to know that in blood loss, sweating, vomiting or diarrhea, the body loses water and ions. While the intake of plain water replaces the water but not the ions. So, this changes the osmolarity of fluids inside your body.
In conclusion, the importance of Na+ and water homeostasis is for keeping the optimal functions of cells.

Some information about edema in the brain tissue it is mentioned in the book so it is for your general knowledge: it is just read only

Rapid changes in cell volume as a result of hyponatremia can have profound effects on tissue and organ function, especially the brain. A rapid reduction in plasma sodium concentration, for example, can cause brain cell edema and neurological symptoms, including headache, nausea, lethargy, and disorientation. If plasma sodium concentration rapidly falls below 115 to 120 mmol/L, brain swelling may lead to seizures, coma, permanent brain damage, and death. Because the skull is rigid, the brain cannot increase its volume by more than about 10 percent without it being forced down the neck (herniation), which can lead to permanent brain injury and death. When hyponatremia evolves more slowly over several days, the brain and other tissues respond by transporting sodium, chloride, potassium, and organic solutes, such as glutamate, from the cells into the extracellular compartment. This response attenuates osmotic flow of water into the cells and swelling of the tissues (Figure 25-7). Transport of solutes from the cells during slowly developing hyponatremia, however, can make the brain vulnerable to injury if the hyponatremia is corrected too rapidly. When hypertonic solutions are added too rapidly to correct hyponatremia, this intervention can outpace the brain's ability to recapture the solutes lost from the cells and may lead to osmotic injury of the neurons that is associated with demyelination, a loss of the myelin sheath from nerves. This osmotic-mediated demyelination of neurons can be avoided by limiting the correction of chronic hyponatremia to less than 10 to 12 mmol/L in 24 hours and to less than 18 mmol/L in 48 hours. This slow rate of correction permits the brain to recover the lost osmoles that have occurred as a result of adaptation to chronic hyponatremia. Hyponatremia is the most common electrolyte disorder encountered in clinical practice and may occur in up to 15% to 25% of hospitalized patients.
Pictures in the next slide.





>> Intake of plain water happens by drinking

This info here are important

>> Water moves from low osmolarity area into high osmolarity area.

>> The brain tissue is the most sensitive to water intoxication, so those people are subjected to convulsions ,(تشنجات) coma and possible death.

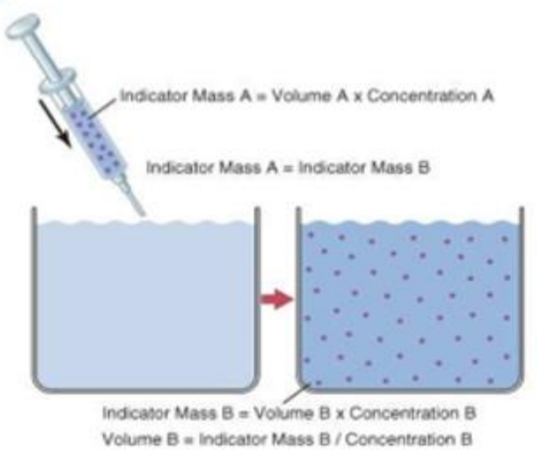
Measurements of body fluids

The volume of a fluid compartment in the body can be measured by placing an indicator substance in the compartment, allowing it to disperse evenly throughout the compartment's fluid, and then analyzing the extent to which the substance becomes diluted.

We will study the dilutional method to measure body fluids' volume in our bodies, and this method can be done in different ways. In order to understand these ways, we have to discuss Dilution Principle.

Dilution method for calculating fluid volume

25-4



Elsevier. Guyton & Hall: Textbook of Medical Physiology 11e - www.student

$$\text{Volume B} = \frac{\text{Volume A} \times \text{Concentration A}}{\text{Concentration B}}$$

If 1ml of a 10mg/ml solution is injected into a fluid compartment, and the final concentration is 0.01mg/ml, the volume of the fluid compartment is,

$$\text{Volume B} = \frac{1\ \text{ml} \times 10\ \text{mg/ml}}{0.01\ \text{mg/ml}} = 1000\ \text{ml}$$

In the picture above, we have injected 1mL of a 10mg/mL solution (let's say it's a dye) into a fluid compartment that we don't know its volume. After injection, the final concentration was 0.01mg/mL. Using these information, we can know the volume of the fluid compartment.

We say that: Volume B = (Volume A * Concentration A) / Concentration B = (1mL * 10mg/mL) / 0.01mg/mL = 1000mL

Remember from chemistry 101

Vi*Mi=Vf*Mf

Not required, but to understand

no. of moles in the dye before injection = no. of moles after injection

$$Concentration_{before} * Volume_{before} = Concentration_{after} * Volume_{after}$$

$$Volume_{after} = (Concentration_{before} * Volume_{before}) / Concentration_{after}$$

$$Volume\ B = (Volume\ A * Concentration\ A) / Concentration\ B$$

Properties of tracers used for calculation of volumes

- Properties of an Ideal Tracer The tracer should:
- be nontoxic
- be rapidly and evenly distributed throughout the nominated compartment not enter any other compartment.
- not be metabolized.
- not be excreted (or excretion is able to be corrected for) during the equilibration period
- be easy to measure
- not interfere with body fluid distribution

Total body water measurement:

We should use a substance that can be distributed in all compartments, because we want to measure Total body water volume.

We can use these for total body measurement:
1-Radioactive water (3 H2O, T2O, Tritium) or heavy water (2 H2O, D2O, Deuterium). This will mix with the total body water in just a few hours and the dilution method for calculation can be used. Notes:
*Radioactive water and heavy water are radioactive, but they differ in radioactivity .
-we use these substances in tiny concentrations .
Example: You inject someone with 1mL of heavy water (with known radioactivity) and after a few hours it will mix with the total body water, then you take 1mL of blood and you will find that radioactivity is less than that you have injected and using calculations (dilution principle) you can measure water volume in the body. (Radioactivity is related to concentration, so you can use dilution principle)

2-Antipyrine(It isn't radioactive)
(from the book which is very lipid soluble and can rapidly penetrate cell membranes and distribute itself uniformly throughout the intracellular and extracellular compartments).

Extracellular fluid (ECF) measurement

To measure ECF volume, we can use:
1. 22Na+ (Sodium space). It is radioactive. We can use sodium to measure ECF volume because sodium is mainly found in ECF.
2. 125I-iothalamate. It is also radioactive.
3. Thiosulfate.
4. Inulin (Inulin space). The measurement should be in (30-60) minutes, before the substance gets exchanged between ECF and ICF.

Intracellular fluid (ICF) measurement

To measure ICF volume, we can say:
ICF = Total body water – ECF
There is no need to use substances.

Notes from the book read them they may help you understand better:
1-The distribution of fluid between intracellular and extracellular compartments, in contrast, is determined mainly by the osmotic effect of the smaller solutes—especially sodium, chloride, and other electrolytes—acting across the cell membrane. The reason for this is that the cell membranes are highly permeable to water but relatively impermeable to even small ions such as sodium and chloride. Therefore, water moves across the cell membrane rapidly and the intracellular fluid remains isotonic with the extracellular fluid.
2-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.
3-Extracellular fluid edema occurs when excess fluid accumulates in the extracellular spaces. There are two general causes of extracellular edema: (1) abnormal leakage of fluid from the plasma to the interstitial spaces across the capillaries, and (2) failure of the lymphatics to return fluid from the interstitium back into the blood, often called lymphedema. The most common clinical cause of interstitial fluid accumulation is excessive capillary fluid filtration.

final note ☺ Three conditions are especially prone to cause intracellular swelling: (1) hyponatremia,(A condition where sodium levels in the blood are abnormally low. This causes nausea, vomiting, fatigue, headache or confusion.);
(2) depression of the metabolic systems of the tissues; and
(3) lack of adequate nutrition to the cells. For example, when blood flow to a tissue is decreased, the delivery of oxygen and nutrients is reduced. If the blood flow becomes too low to maintain normal tissue metabolism, the cell membrane ionic pumps become depressed. When the pumps become depressed, sodium ions that normally leak into the interior of the cell can no longer be pumped out of the cells and the excess intracellular sodium ions cause osmosis of water into the cells. Sometimes this process can increase intracellular volume of a tissue area—even of an entire ischemic leg, for example—to two to three times normal. When such an increase in intracellular volume occurs, it is usually a prelude to death of the tissue.

Videos that could help you understand even further more
https://youtu.be/raW6b5kQHPY
https://youtu.be/v3BTWpNTyLU
https://youtu.be/__97EkVevb0

And finally the sheet is finished ☺☺

Best wishes my colleagues
Robert Louis Stevenson once said: ”Don’t judge each day by the harvest you reap but by the seeds that you plant”
Always cheer up ☺