Physiology Lecture 6

Body fluids compartment and constituents

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Lecture Objectives:

*   Describe the volume TBW and percent distribution of body fluids in various compartments in adults' males and females.

*   List factors affecting the volume of body water.

*   Understand how to calculate the volume of various body fluids compartments.

*   Describe the composition of extracellular fluid (ECF) and intracellular fluid compartment (ICF) and the ionic distribution in these compartments.

*   Explain the Indicator-dilution method and its use for measuring body fluids volumes.

*   Understand how to determine volumes of specific body fluid compartments using various substances and the volume of distribution of these substances.

General principles

1. Homeostasis requires the maintenance of a relatively constant volume and stable composition of the body fluids.

2. To stabilize body fluids, fluid intake (by ingestion or synthesized because of metabolism) should be equal to fluid output.

3. Fluid intake can be controlled by thirst mechanism, whereas the most important means by which the body controls the output of water and electrolytes (to match the intake) is by the kidneys.

يمكن تسخدم منها الماء الكلول (F)

in = out

العطش

by kidneys

Body fluid compartments

Total body fluid constitutes 55-60% of the body weight in young men and 45-50% of body weight in young women. This is due to the greater amount of adipose tissue in women than in men. Total body fluid is distributed between;

1. Intracellular fluid (⅔ of body fluid = 40% of total body wt.)

2. Extracellular fluid (⅓ of body fluid = 20% of total body wt.). ECF can be divided into subcompartments.

   a. interstitial fluid (¾ extracellular fluid). This fluid surrounds all cells except blood cells and includes the lymph. Edema is the palpable swelling produced by expansion of the interstitial fluid volume.

   b. blood plasma (¼ extracellular fluid); It is the fluid portion of the blood.

   c. Transcellular fluid volume; This ECF subcompartment represents fluid in the lumen of structures lined by epithelium and includes **digestive secretion; sweat; cerebrospinal fluid (CSF); pleural, peritoneal, synovial, intraocular,** and **pericardial fluid; bile;** and **luminal fluid** of the gut, thyroid, and cochlea.
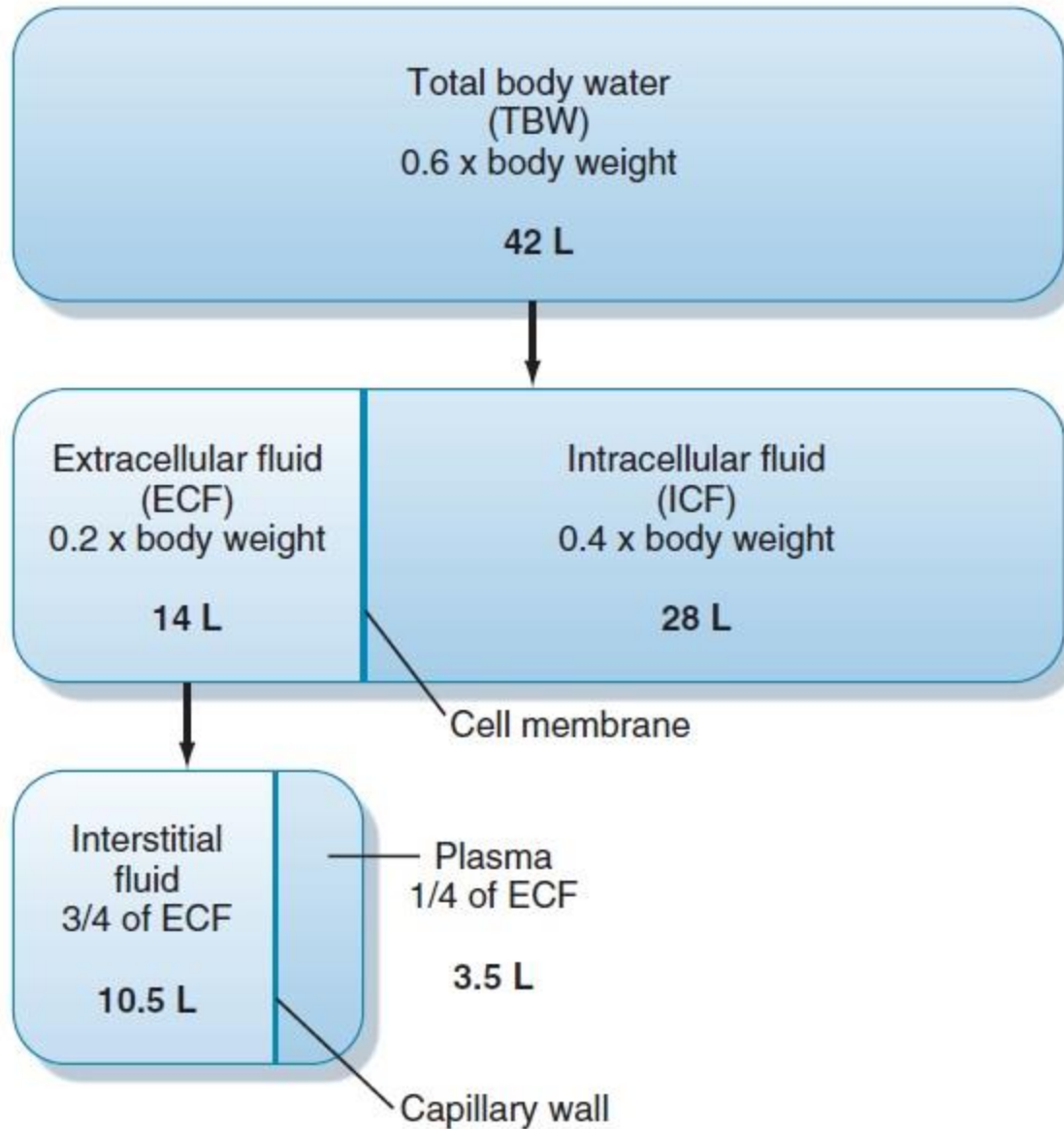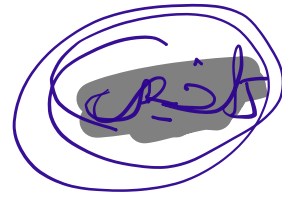
Total body water (TBW)
0.6 x body weight

42 L

Extracellular fluid (ECF)
0.2 x body weight

14 L

Intracellular fluid (ICF)
0.4 x body weight

28 L

Cell membrane

Interstitial fluid
3/4 of ECF

10.5 L

Plasma
1/4 of ECF

3.5 L

Capillary wall

Relationship Between the Volumes of the Various Body Fluid Compartments. The actual values shown are for an individual weighing 70 kg. → Averge

Osmolar Substances in Extracellular and Intracellular Fluids

| Substance	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^{2+}	1.3	1.2	0
Mg^{2+}	0.8	0.7	20
Cl^-	106	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	299.8	300.8	301.2
Corrected osmolar activity (mOsm/L)	282.0	281.0	281.0
Total osmotic pressure at 37°C (98.6°F) (mm Hg)	5441	5423	5423
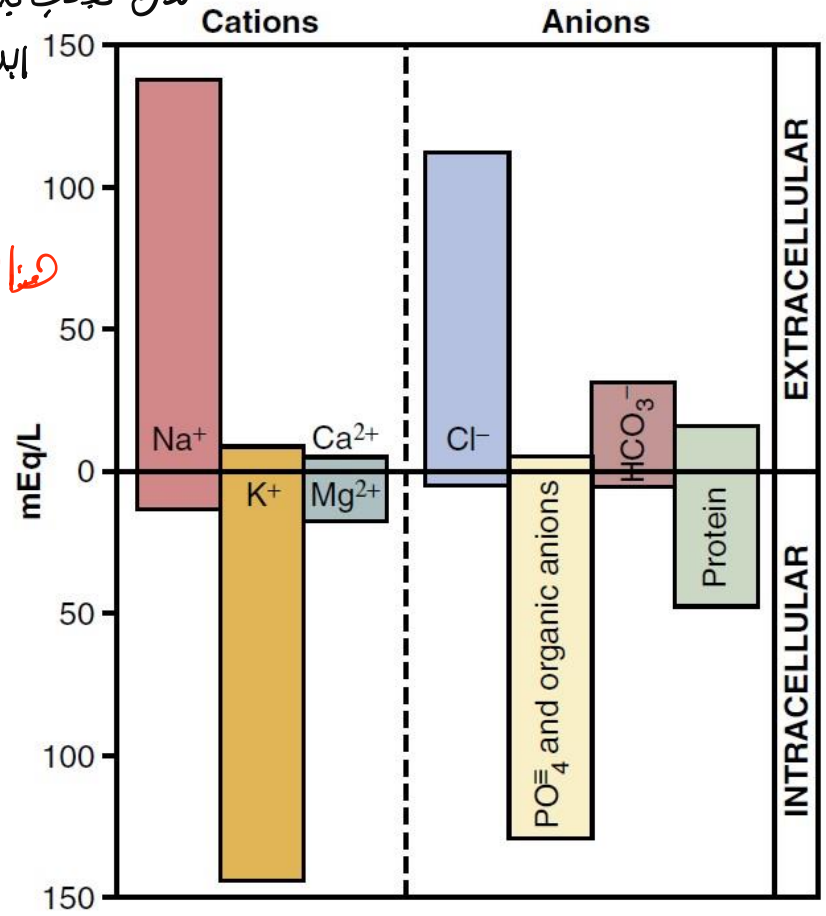
Major cations and anions of the intracellular and extracellular fluids. The concentrations of Ca^{2+} and Mg^{2+} represent the sum of these two ions. The concentrations shown represent the total of free ions and complexed ions.

Note:-

* The ratio of total body fluid to total body weight declines with advancing age and with obesity.

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

Measurement of fluid volumes (the indicator-dilution method);

It can be obtained by placing an indicator substance in the compartment fluid that we would like to measure. After the even dispersion of the indicator, the volume of the compartment can be calculated according to the formula,

Where V = volume (in ml or L)

A = the substance injected intravenously (in g,

$$V = \frac{A}{C}$$

Kg, or mEq)

C = Final concentration attained (in g/ml, g/L,

mEq/ml, or mEq/L)

Or the equation can be written in the form;

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

* والآن شلون نقسناه ونعرف حجم الماء في جسمنا ؟؟   بوسائل القياس وعادة

التخفيف

نستخدم   ـ: <u>dilution method</u>

• نحاول نفهمها بمثال البحيرة لكن بدنا نعرف شنقد حجم الماء فيها،
وهذا من طريق أننا نجيبوا مادة معينة من مادة عالية التركيز (التركيز معلوم)
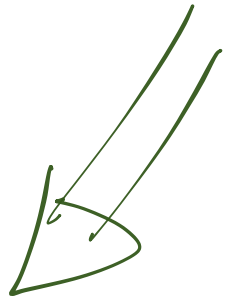ثم نضع هذه المادة في البحيرة ، ح يصير فيها diffusion، فنأخذ بعد يومين
نحنا نرجع من ماء البحيرة ونحسب التركيز له ، الآن لدينا 3 معطيات وعن طريق القانون
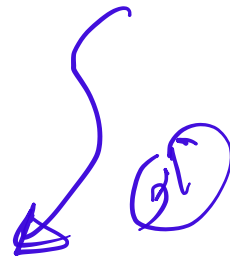
$$C_1 \times V_1 = C_2 \times V_2$$

* وهذه هي طريقة ال ((dilution)).

$$A = C * V \longrightarrow V * V / g = \textcircled{g}$$

$$V = \dfrac{A}{C} \quad \begin{array}{l} \rightarrow \text{كمية} \\ \rightarrow \text{تركيز} \end{array}$$

في حالة كيف نكوّن كمية كاملة من ال $\underline{V}$.

$$V_1 * c_1 = V_2 * C_2$$

Measurement of fluid volumes (cont.)

Markers; all markers share four qualities

1. They are measurable
2. They remain in the compartment being measured
3. They do not alter water distribution in compartment being measured
4. They are nontoxic

✱ نطبق الطريقة على جسم الانسان بإضافة مادة ذات تركيز معين

ولكن ليست أي مادة بل لها شروط :.

① — قابلة للقياس

② تبقى في الأماكن التي نريد قياسها

③ لا تتوزع تلقائ توزيع المادة في هذا
   المكان

④ طرق تغير بسيطة

Measurement of fluid volumes (cont.)

أحسن مادة التوزيع حقها كل مكان غير حها نستخدم الماء الثقيل

حواب يمكن استخدامها للقياس ←

* For total body fluid measurement, the unstable radioactive water (tritium, ^3H_2O) is the substance of choice. Heavy water (deuterium, ^2H_2O) can also be used, however it is a stable isotope. *Antipyrine*, urea, and thiourea can also be used to measure total body fluid volume.

نستخدم مادة لا تنجبر (ECM)

* For extracellular fluid volume measurement two types of substances are used;

1. Saccharides such as *inulin*, sucrose, raffinose, and mannitol.

2. Ions such as thiosulfate, thiocyanate, and radionuclides of iothalamate, sulphate $(SO_4)^{-2}$, chloride (Cl^-), Bromide (Br^-), and Sodium (Na^+). However, mild error is obtained if Na is used since small amounts of Na may diffuse into the cell.

* وإذا بدي أقيس بس داخل ال blood Vishes دم بستخدم مواد مثل البروتينات المشحنة

Measurement of fluid volumes (cont.)

* For the calculation of intracellular volume (direct measurement is not possible) this formula is used,

* intracellular volume = Total body water – Extracellular volume

* Measurement of plasma volume can be achieved by either one of the following two dilution methods

    a. A substance that neither leave the vascular system nor penetrate the erythrocytes. Such substances include;

       1. Evans blue dye (T-1824), also has the advantage of being avidly bound to plasma proteins

       2. Radio-Iodinated Human Serum Albumin (^{125}I-albumin) is also called RISA

       3. Radioiodinated human gama globulin and fibrinogen (preferable)

    b. The use of tagged erythrocytes by radioactive isotopes of phosphorus (^{32}P), iron (^{55,59}Fe), and chromium (^{51}Cr). These RBCs are injected intravenously, and their volume of distribution is measured.

Measurement of fluid volumes (cont.)

* For the calculation of interstitial fluid volume the following formula is used,

* Interstitial fluid volume = Extracellular fluid volume – Plasma volume

* For the calculation of blood volume the following formula is used,

$$\textbf{Total blood volume (L)} = \frac{\textbf{Plasma volume (L)}}{\textbf{1} - \textbf{Hematocrit}} (PCV)$$

نسبة حجم الكريات الحمر إلى حجم الدم
المحيطة
%40-45 في
عن طريق السحب العالي centrifuge الـ tube

Test Question:

Q. Extracellular fluid in adults differs from intracellular fluid in that its:

A. Volume is greater.

B. Tonicity is lower.

C. Anions are mainly inorganic.

D. Potassium:sodium molar ratio is higher.

E. pH is lower.