UNIVERSITY OF MEDICAL SCIENCES, ONDO

DEPARTMENT OF PHYSIOLOGY

PHS 212: BLOOD AND BODY FLUID PHYSIOLOGY

LECTURER: MR A.O. AKINOLA

OBJECTIVES

- Introduction
- Definition of body fluids and body fluid compartments
- Physiological variation of body fluid volumes
- List the ionic composition of different body compartments
- Regulation of body fluid volumes
- Techniques for quantifying various body fluid volumes

Introduction

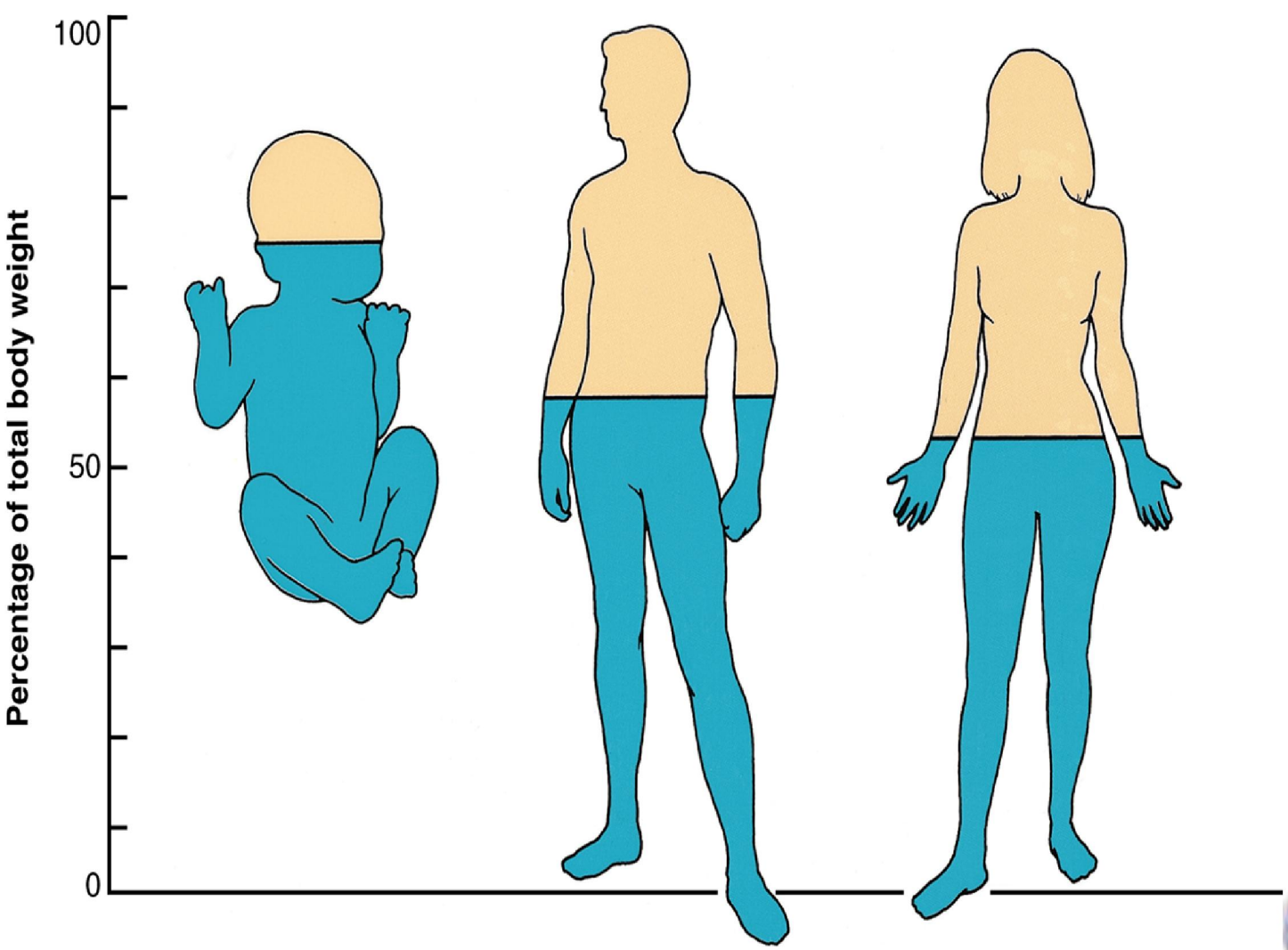
- Water is the major constituent of all body fluid compartments.
- In an adult human, average of 70-kilogram
- Total body water is about 60 per cent of the body weight, or about 42 liters.

PHYSIOLOGICAL VARIATION OF BODY FLUID VOLUME

Most of the variation in body fluid between individuals is as a result of variation in amount of body fat or adipose tissue (fat is only about 10% water)

- Infant: 73-80%
- Male adult: 60%
- Female adult: 40-50%
- Effects of obesity
- Old age 45%

PERCENTAGE OF H_2O IN TISSUES



Normal Daily Fluid Input and Output

Inputs	Outputs
➢ Ingestion	➢Gut (Faeces 100ml)
▪Fluid (1.25 Liters)	➢Urine (1.5 Liters)
▪Food (1 Liter)	➢Breathing/Skin (900ml)
➢Metabolism (350 ml)	➢Sweating (100ml)
➢Total (2.6 Liters)	➢Total (2.6 Liters)

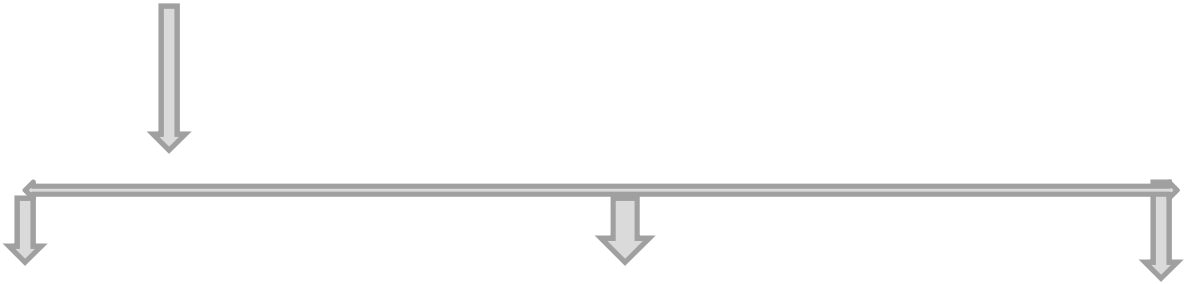
Abnormal Fluid Input and Output

Inputs	Outputs
➢Injection/Infusion	➢Gut
➢Hyperdipsia	▪Vomiting
	▪Diarhoea
	➢Skin- Burns
	➢Sweating- Excessive
	➢Urine- Diabetes insipidus
	➢Haemorrhage

FLUID COMPARTMENTS

EXTRA CELLUAR FLUID

INTRA CELLULAR FLUID



PLASMA

INTERSTITIAL FLUID

TRANSCELLULAR FLUID

- **CSF**
- **Intra ocular**
- **Pleural**
- **Peritoneal**
- **Synovial**
- **Digestive Secretions**

PERCENTAGE OF WATER IN TISSUES

Average 70 kg person total body weight

- **42 litres** total H2O 60%
- **28 liters** Intracellular fluid (ICF) 40%
- **14 liters** Extracellular fluid (ECF) 20%

ECF is divided into ¾ ISF and ¼ plasma water

- **10.5** liters Interstitial fluid (ISF) 15%
- **3.5** liters Plasma water 5%
- All the transcellular fluids together constitute about 1 to 2 liters.

IONIC COMPOSITION OF BODY FLUIDS (mEq/l)

Substance	ICF	ISF	Plasma
Cations			
Na^+	14	140	142
K^+	150	5	5
Ca^{2+}	2	5	5
Mg^{2+}	30	2	2
Anions			
Cl^-	10	113	113
HCO_3^-	10	27	27
HPO_4^-/$H2PO_4^-$	113	2	2
SO_4^{2-}	20	1	1
Protein	74	2	16

REGULATION OF BODY FLUID VOLUME

The hypothalamus achieve this by two mechanisms:

- Thirst mechanism
- ADH mechanism

THIRST MECHANISM

- Thirst centre in the hypothalamus contains osmoreceptors
- When ECFV decreases then osmolarity increases
- Osmoreceptors are stimulated and this activate the thirst centre
- Thirst is initiated
- The person feels thirsty and drink water
- ECF volume increases and ECF osmolarity decreases

ADH MECHANISM

- When ECFV decreases , ECF osmolarity increases
- Supraoptic nucleus in the hypothalamus is stimulated
- ADH is released
- ADH causes retention of water by facultative reabsorption
- ECFV increases and osmolarity decreases
- On the contrary, when ECFV increases
- No ADH is released, decrease water reabsorption

MEASUREMENT OF BODY FLUID VOLUME

- Can be done both directly (indicator dilution method) and indirectly

- By injecting substances that will stay in one compartment

- Then calculate the volume of fluid in which the test substance is distributed (volume of distribution of injected material)

- Volume of distribution

$$= \frac{\text{amt. of substance injected- amt. excreted/metabolized}}{\text{concentration of the substance in the sample}}$$

Example: 150mg of sucrose is injected into a 70kg man. The plasma sucrose level after mixing is 0.01mg/ml, and 10mg has been excreted or metabolized during the mixing period. Calculate the volume of distribution of sucrose

CHARACTERISTICS OF MARKER SUBSTANCE/INDICATOR

- Must be non-toxic
- Must mix evenly throughout the compartment being measured
- Must have no effect of its own on the distribution of water or other substances in the body
- It must be unchanged by the body during mixing period, or the amount changed must be known
- It must be easy to measure

MEASUREMENT OF TOTAL BODY WATER

- Using indicator dilution method
- Indicators include:
- Radioactive water (tritium, $^{3}H_2O$) or heavy water (deuterium, $^{2}H_2O$) and antipyrine
- They mix with TBW within few hours of injection

MEASUREMENT OF ECF VOLUME

- Using indicator dilution method
- Indicators include:
- Radioactive sodium, radioactive chloride, thiosulphate ion, inulin, mannitol and sucrose
- The substances mix almost completely throughout ECFV within 30-60mins

MEASUREMENT OF PLASMA VOLUME

- Using indicator dilution method

- Indicators include:
  Evan's blue (T-1824) and radioactive iodine(^{131}I)

- The substance binds with plasma proteins strongly

- Diffuses into ISF in small quantity or not at all

INDICATORS USED FOR MEASURING PLASMA VOLUME, ECF VOLUME AND TOTAL BODY H_2O

Compartment	Criterion	Indicators
• Plasma	Substance should not cross capillaries	• Evans blue dye; • radioiodinated fibrinogen; • radioiodinated albumin
• ECF volume	Substance should cross capillaries but not cross cell membranes	Isotonic solutions of sucrose, inulin, mannitol, NaCl
• Total body H_2O (TBW)	Substance distributes evenly in ICF & ECF	Heavy H_2O, tritiated H_2O, aminopyrine, antipyrine

Blood volume /Markers used

Obtained from plasma volume and hematocrit

- Total blood volume = $\frac{\text{Plasma volume}}{\text{1- Hematocrit}}$

- Example: If the plasma volume is 4 liters and the hematocrit is 0.45, total blood volume is ?

Take this problem:

100 mg of sucrose is injected into a 70 kg man. The plasma sucrose level after mixing is 0.01 mg/ml. If 5 mg has been metabolized during this period, then, what is the ECF volume?

9.5 L

14 L

17.5 L

10 L

COMPARTMENTS WITH NO COMPARTMENT-SPECIFIC SUBSTANCE

Determine by subtraction:

- How would you measure ICF volume?
- Cannot be measured; it is calculated (estimated)..
- ICF volume = Total body H_2O – ECF volume

Interstitial volume:

- Can not be measured directly
- Interstitial Fluid Volume (ISFV):
  ISFV = ECFV - PV

Please emulate the biblical Bereans (Acts 17:11)

END OF LECTURE