COMPOSITION AND DISTRIBUTION OF BODY FLUIDS

Dr Katek Balapala

Learning Objectives

- Know the distribution of bodily fluids and composition of intracellular and extracellular fluid.
- Know how to calculate the volume of the different fluid compartments.
- Know how to calculate the shifts in osmolarity.
- Osmolality
- Tonicity , Donnan effect

Homeostasis

Maintenance of relatively stable internal environment.

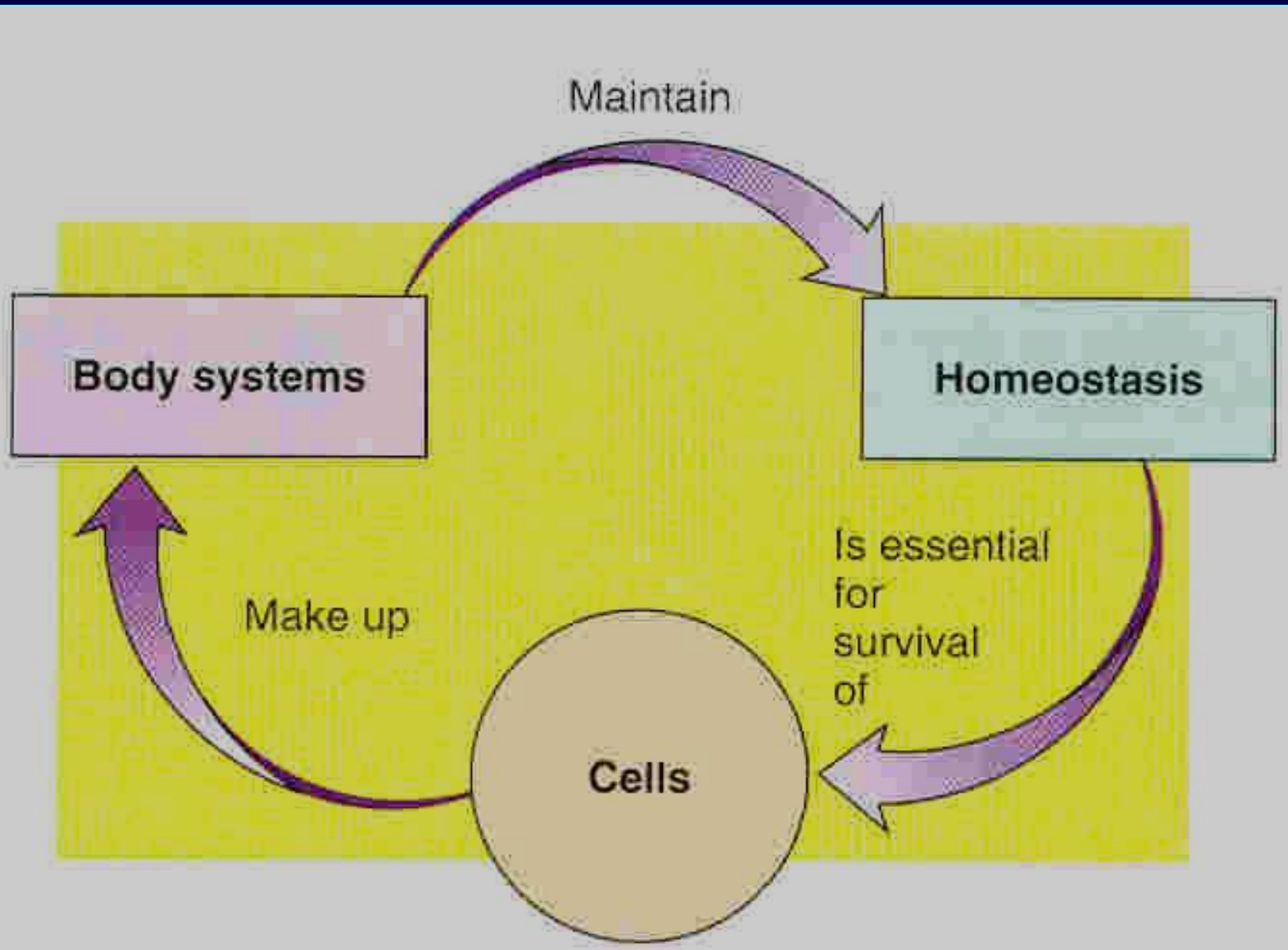
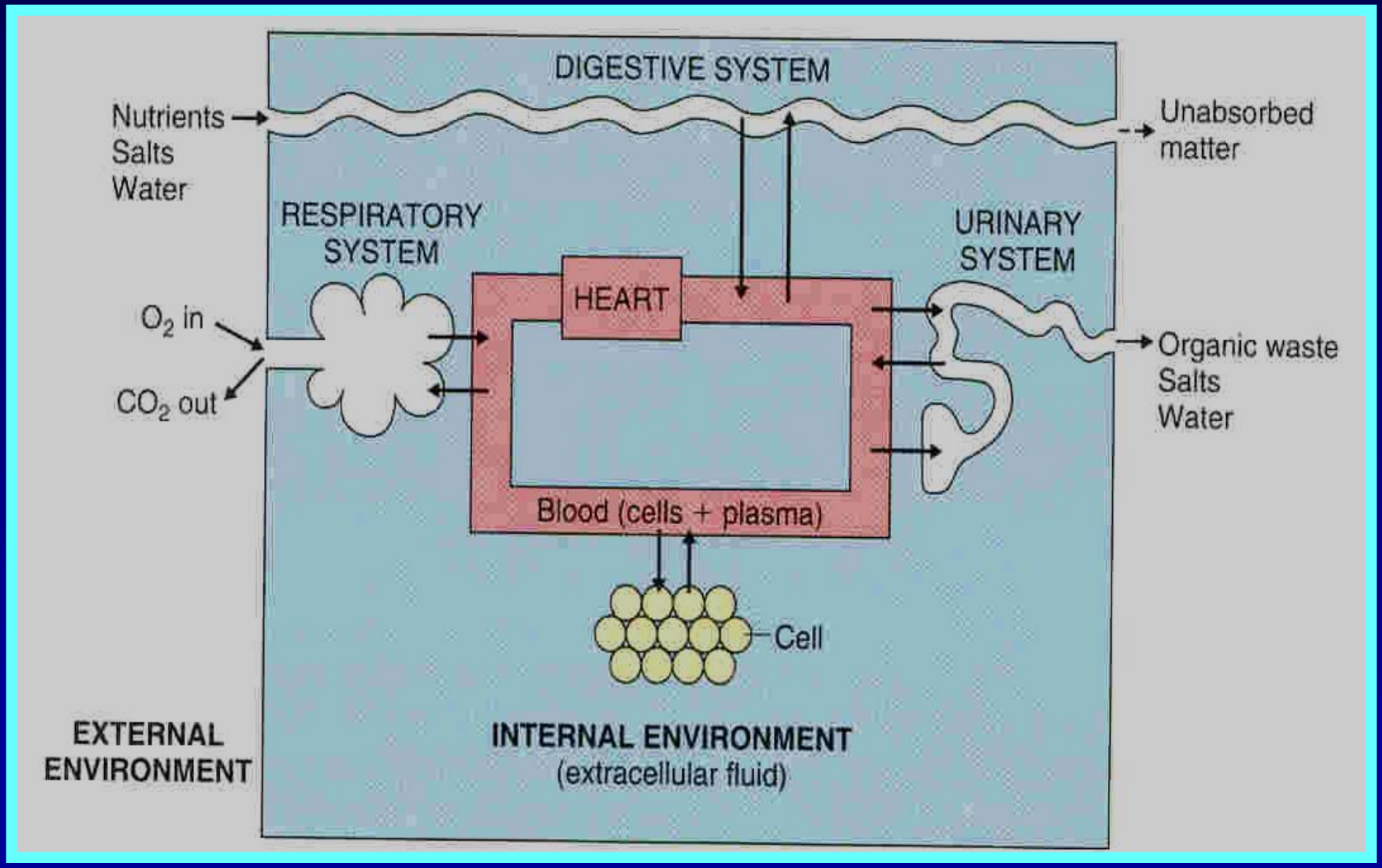
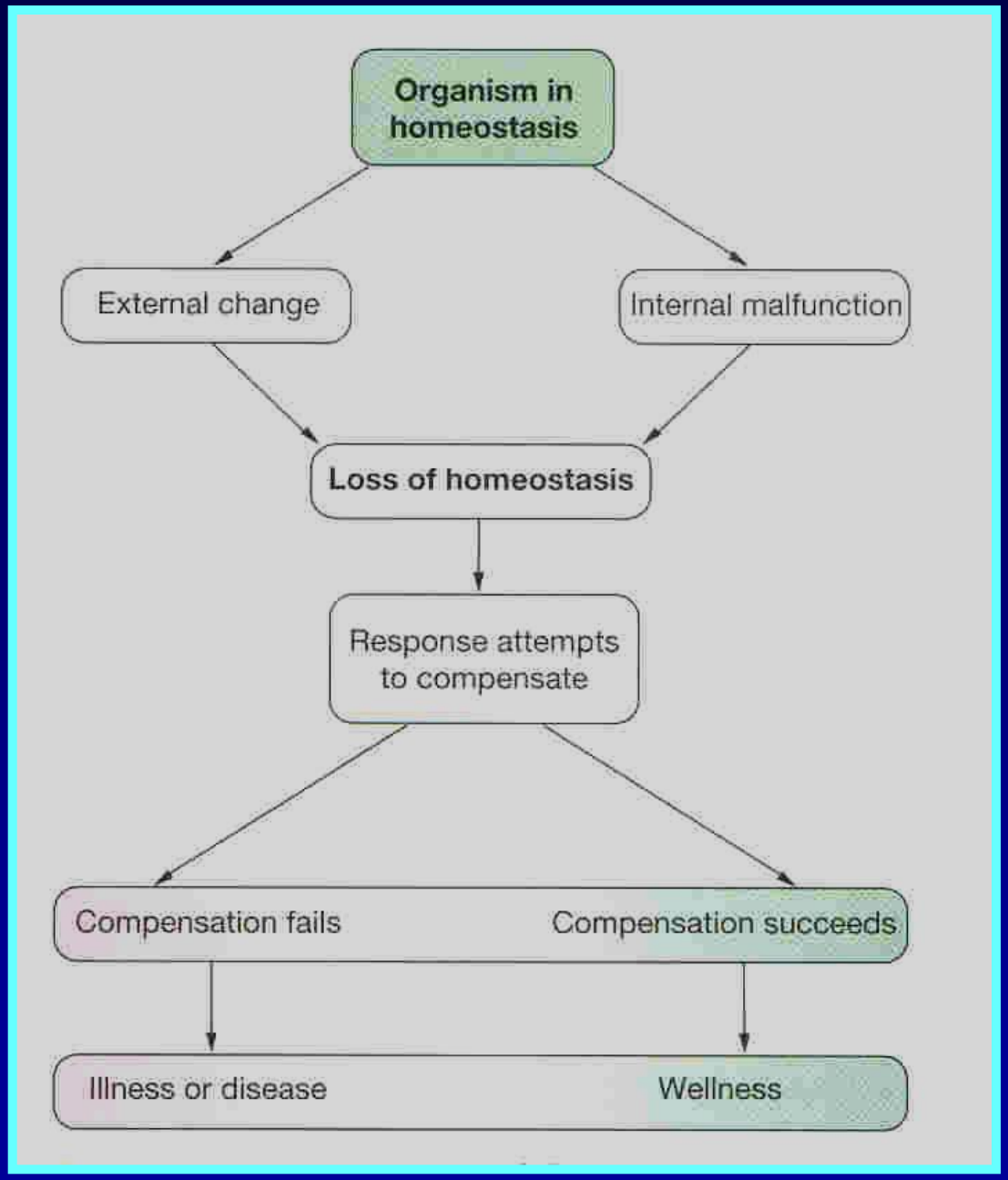
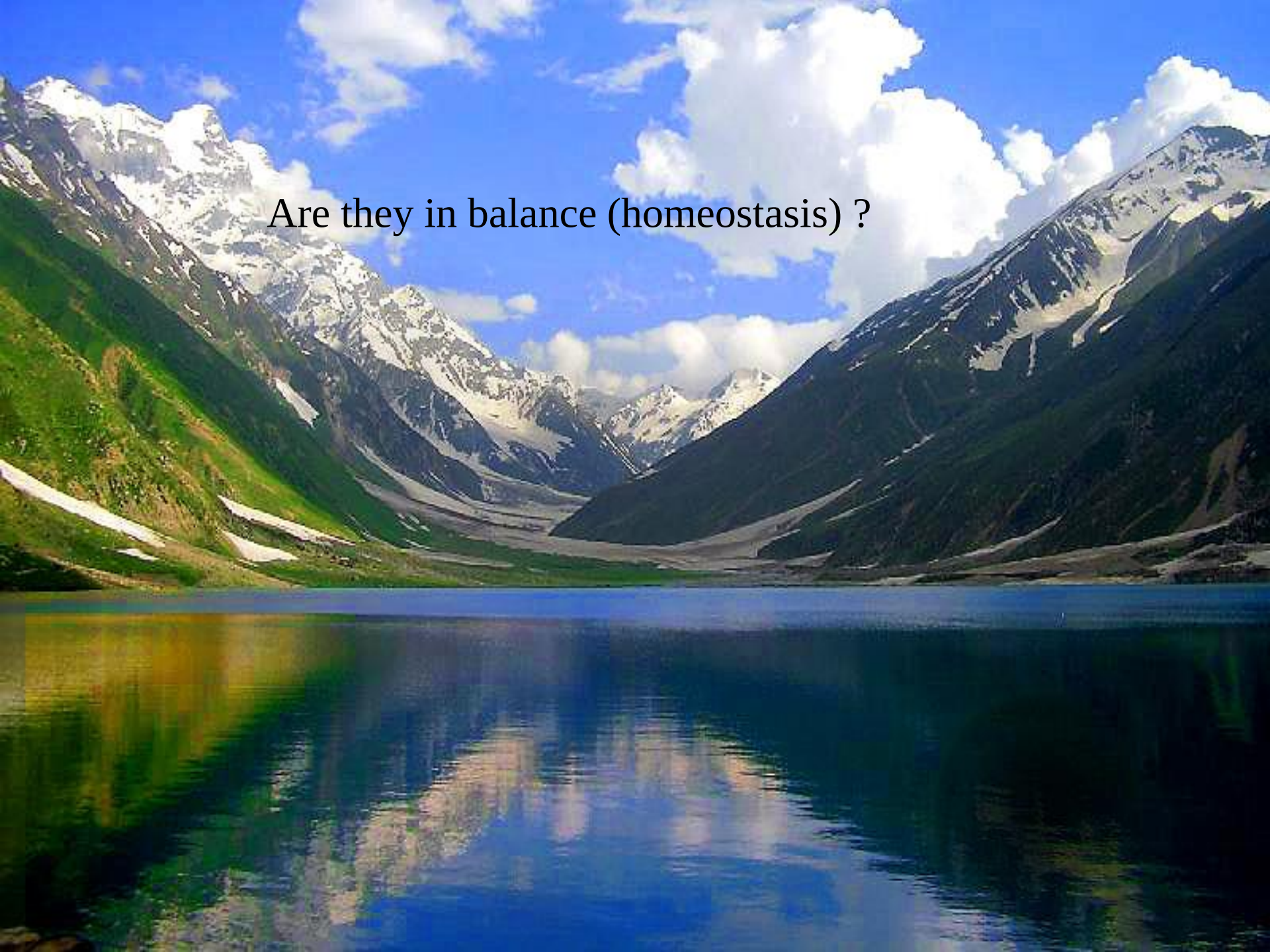

Maintain
Body systems
Homeostasis
Is essential for survival of
Make up
Cells

FIGURE 1-3


DIGESTIVE SYSTEM
Nutrients
Salts
Water
Unabsorbed
matter
RESPIRATORY
SYSTEM
URINARY
SYSTEM
HEART
O_2 in
CO_2 out
Organic waste
Salts
Water
Blood (cells + plasma)
Cell
EXTERNAL
ENVIRONMENT
INTERNAL ENVIRONMENT
(extracellular fluid)


Organism in homeostasis
External change
Internal malfunction
Loss of homeostasis
Response attempts to compensate
Compensation fails
Compensation succeeds
Illness or disease
Wellness


Are they in balance (homeostasis) ?

Water Balance

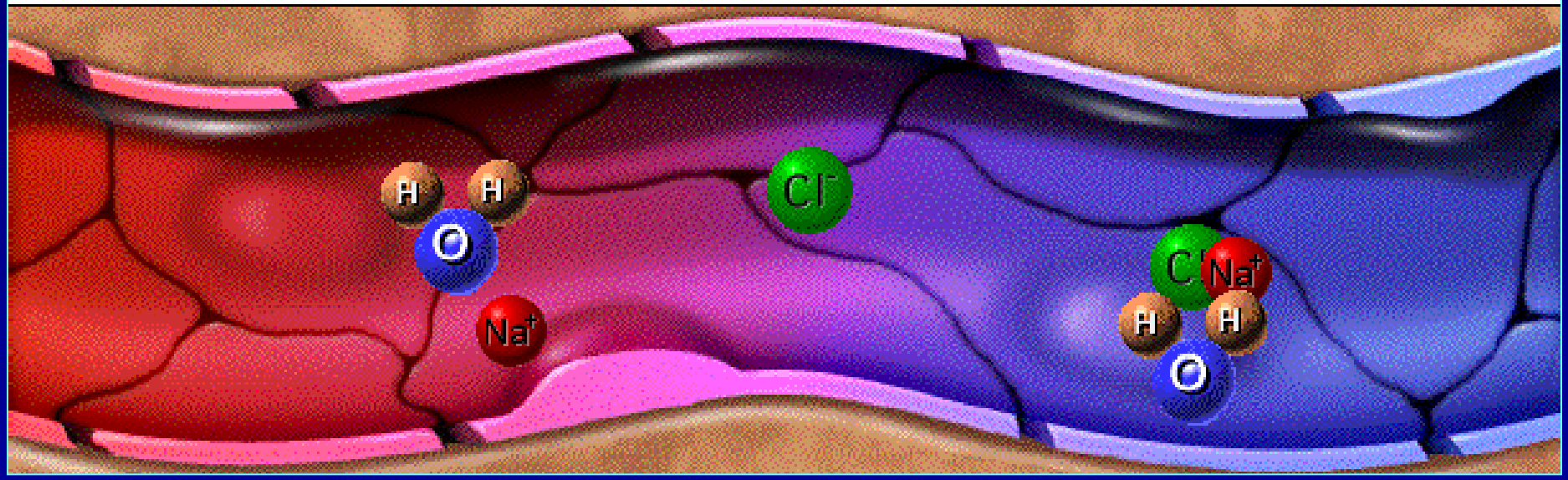
Table 25-1. Daily Intake and Output of Water (ml/day)

	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

The body must maintain a relatively constant volume and composition of the body fluids under a wide variety of conditions.

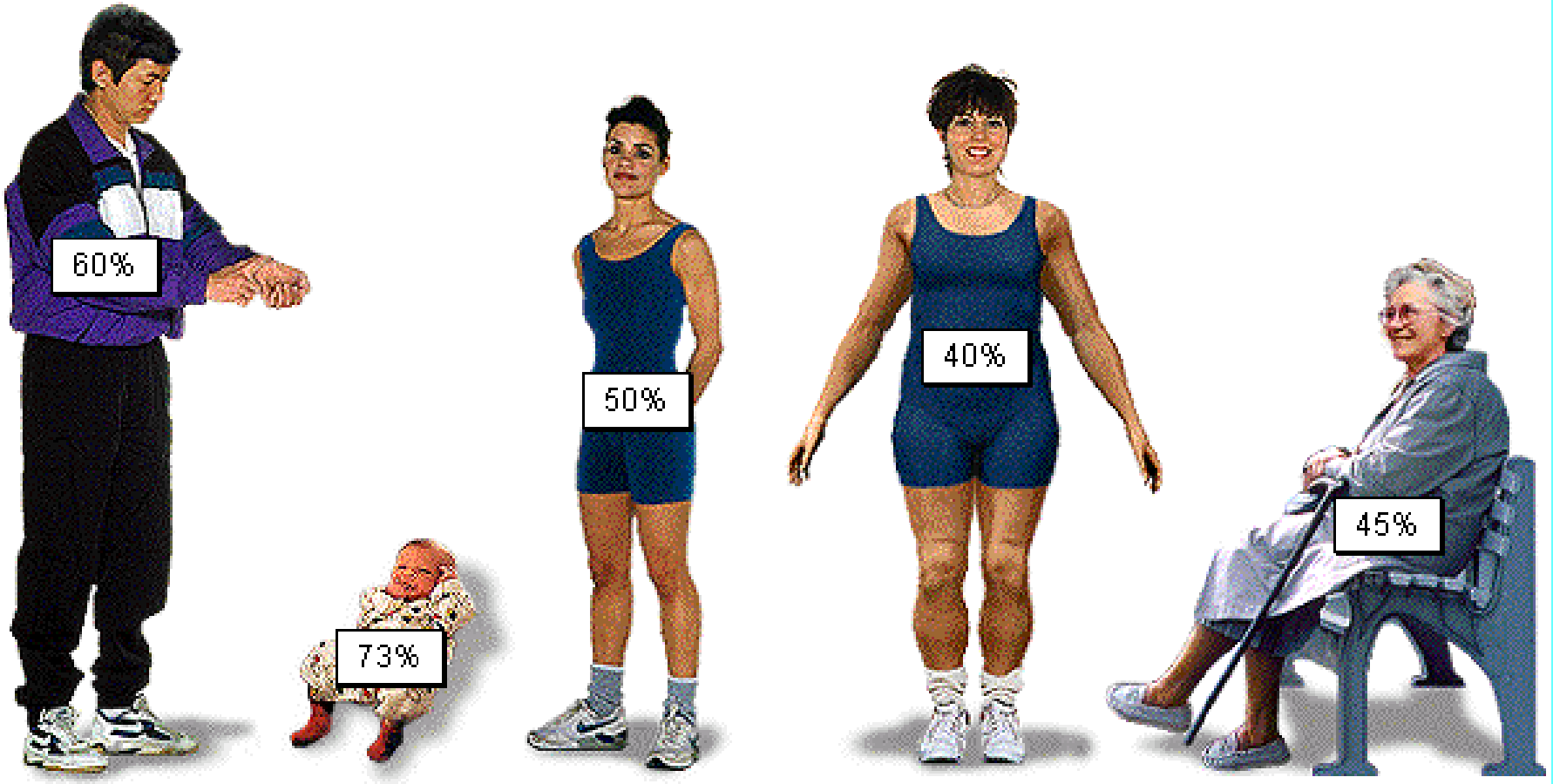
Roles of Water

- Temperature regulation
- Protective cushion
- Lubricant
- Reactant
- Solvent
- Transport



Percentage of Water in the Body

Click each of the people below to determine the approximate percentage of water in their bodies.



FACTORS AFFECTING

Total Body Water

- varies depending on body fat:
  - infant: 73%
  - male adult: 60%
  - female adult: 40-50%
  - effects of obesity ↓
  - Old age 45%

COMPOSITION OF BODY FLUIDS

ELECTROLYTES

Electrolytes are charged particles (**ions**) that are dissolved in body fluids.

Electrolytes (Dissolved Ions)

Major Positive Ions (**Cations**)

- Na^+ Sodium ion, Na^+
- K^+ Potassium ion, K^+
- Ca^{2+} Calcium ion, Ca^{2+}
- Mg^{2+} Magnesium ion, Mg^{2+}

Major Negative Ions (**Anions**)

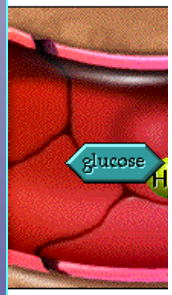
- Cl^- Chloride ion, Cl^-
- HCO_3^- Bicarbonate ion, HCO_3^-
- HPO_4^{2-} $H_2PO_4^-$ Phosphate ions, HPO_4^{2-} & $H_2PO_4^-$
- SO_4^{2-} Sulfate ion, SO_4^{2-}

Organic acids

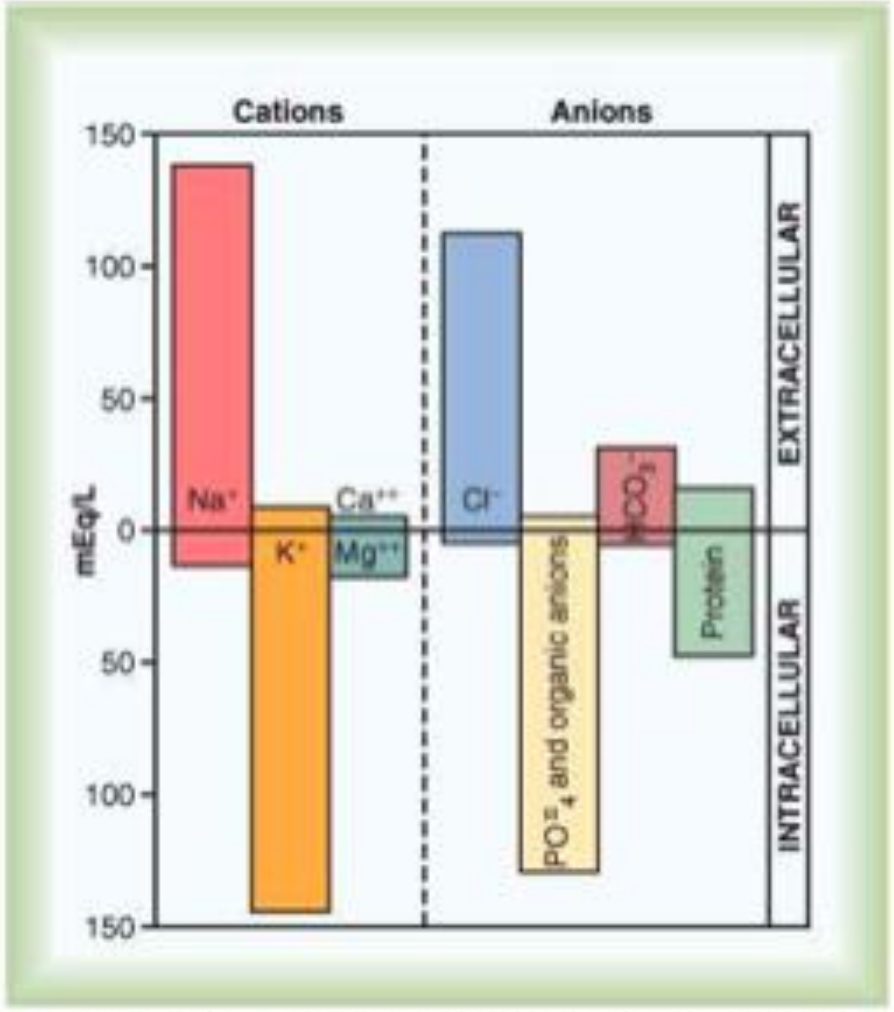
Proteins

Composition of Body Fluids

You are looking at **plasma**, a typical body fluid.



25-1



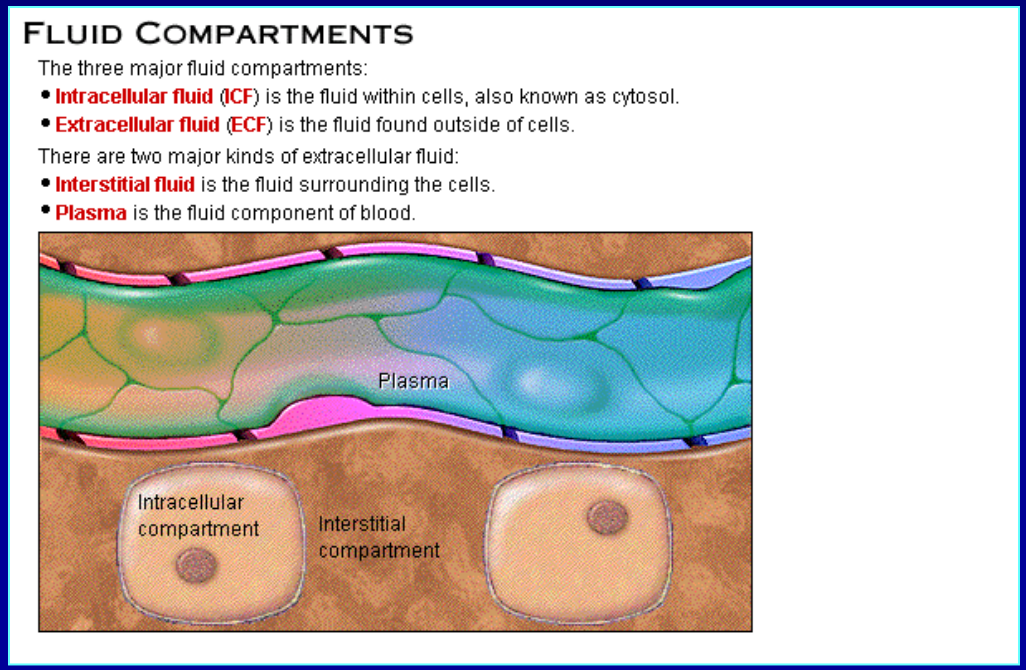
COMPOSITION OF BODY FLUIDS

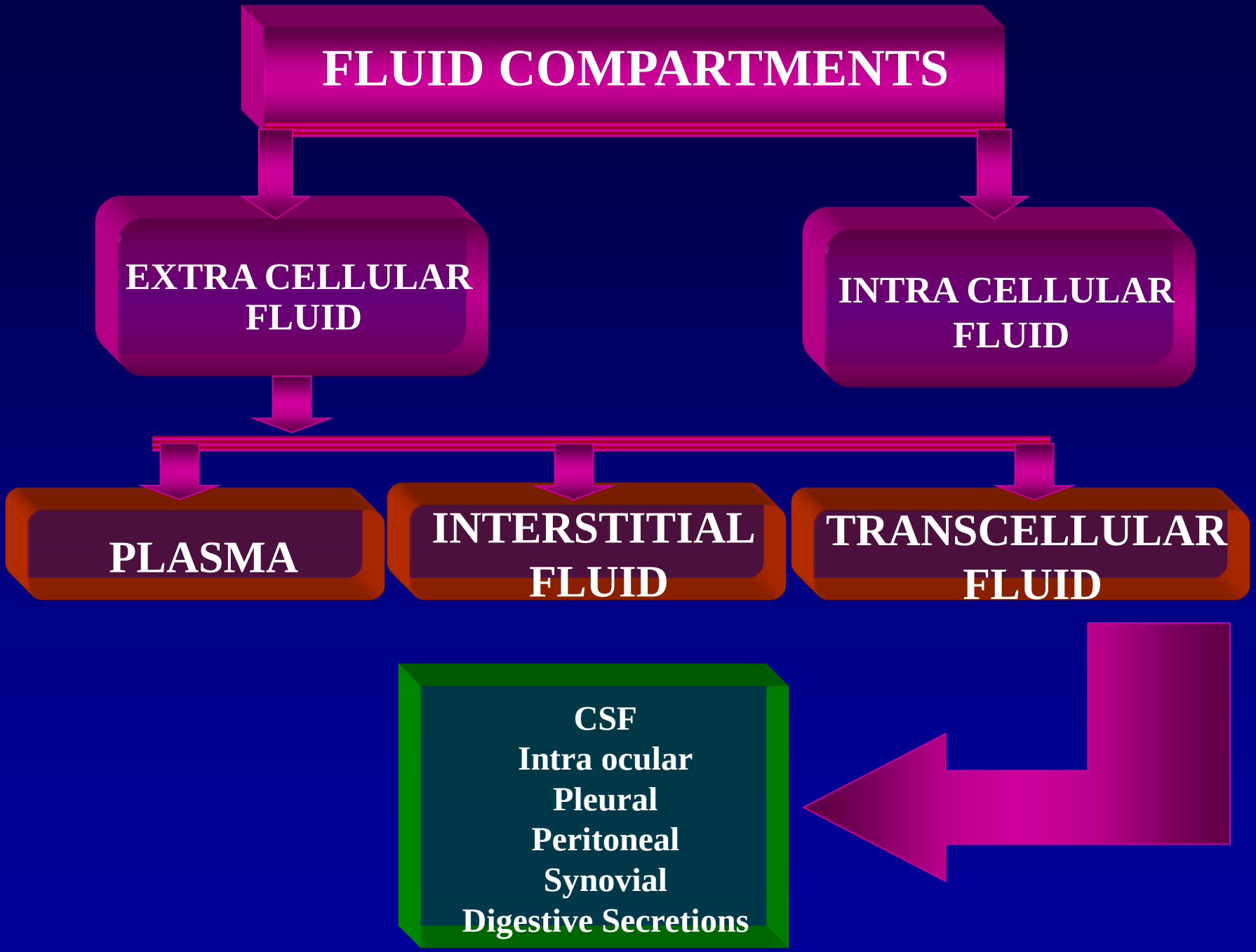
CATIONS (mmol/l)	Plasma	Interstitial	Intracellular
Na	142	139	14
K	4.2	4.0	140
Ca	1.3	1.2	0
Mg	0.8	0.7	20
ANIONS (mmol/l)			
Cl	108	108	4.0
HCO3	24.0	28.3	10
Protein	1.2	0.2	4.0
HPO4	2.0	2.0	11

If imbalance = disease, renal failure, dehydration…..

IMPORTANCE

- **Maintaining ECF volume is critical to maintaining blood pressure**
- **ECF osmolarity is of primary importance in long-term regulation of ECF volume**
  - **ECF osmolarity maintained mainly by NaCl balance:**
  - **intake: 10.5g/d**
  - **output: 10g/d in urine**




FLUID COMPARTMENTS
EXTRA CELLULAR FLUID
INTRA CELLULAR FLUID
PLASMA
INTERSTITIAL FLUID
TRANSCELLULAR FLUID
CSF
Intra ocular
Pleural
Peritoneal
Synovial
Digestive Secretions

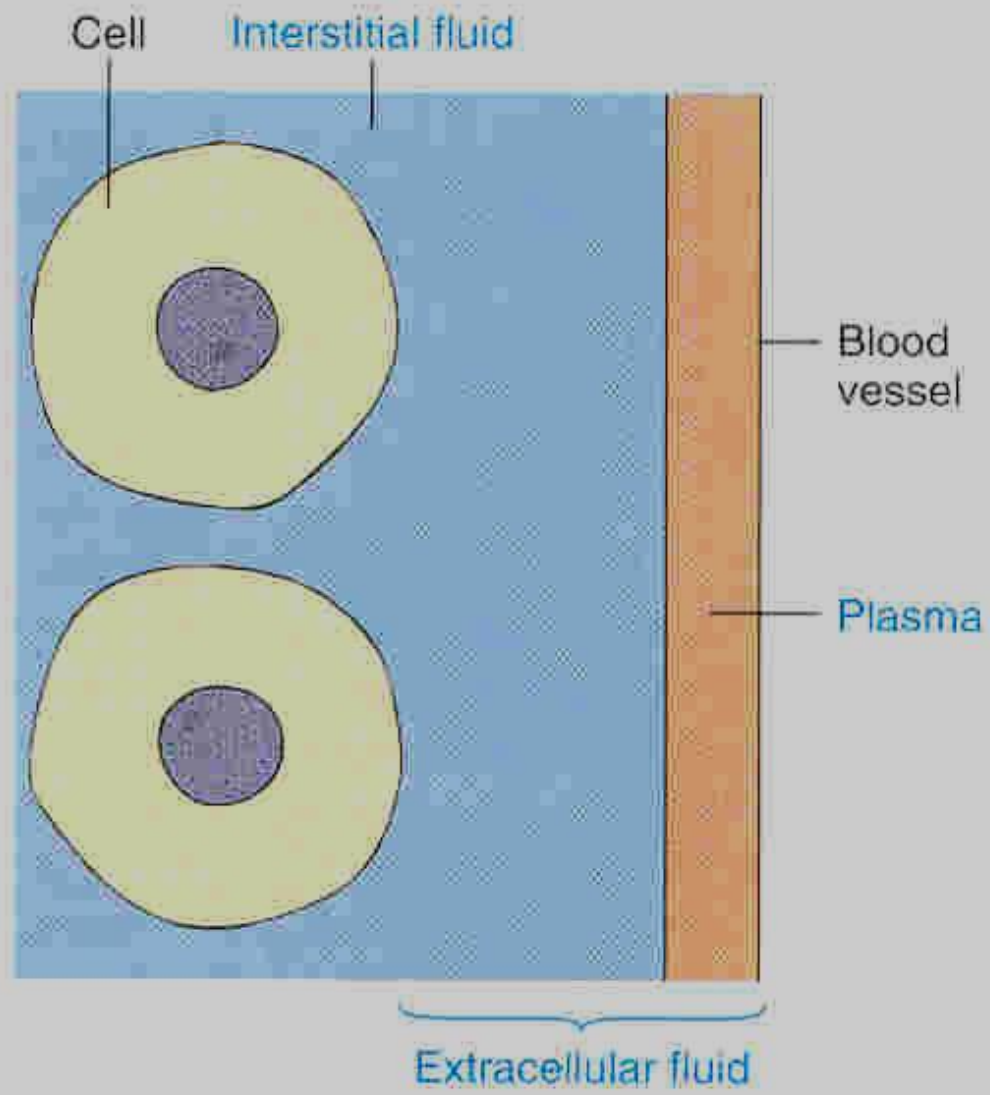
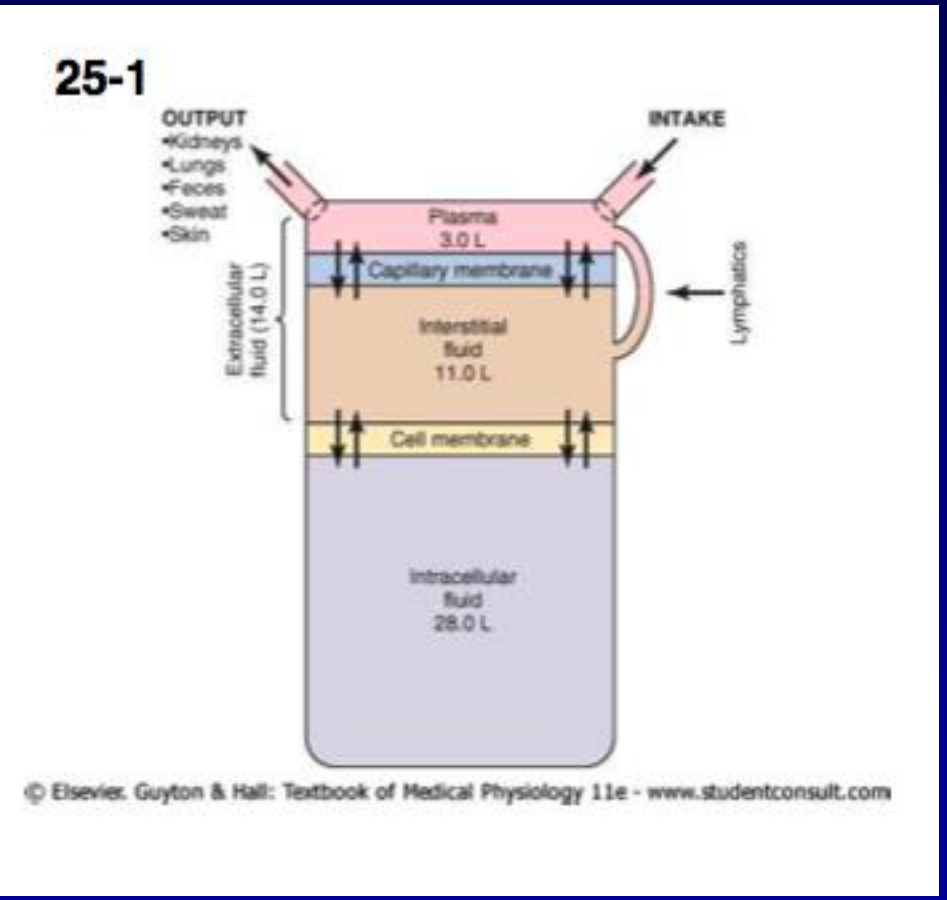

Cell
Interstitial fluid
Blood vessel
Plasma
Extracellular fluid

FIGURE 1-2

Distribution of Bodily Fluids



- Most of the H_2O is intracellular.
- The total body H_2O is ~ 60% of the body weight (70 kg) (~ 42 L).
- 50% of the body weight in adult female

The % depends on age, gender, and degree of obesity.

VOLUME OF BODY FLUIDS IN 70 kg MAN

TOTAL VOLUME

42 L

INTRACELLULAR FLUID

28L(ROUGHLY 2/3 OF TBW)

EXTRA CELLULAR FLUID

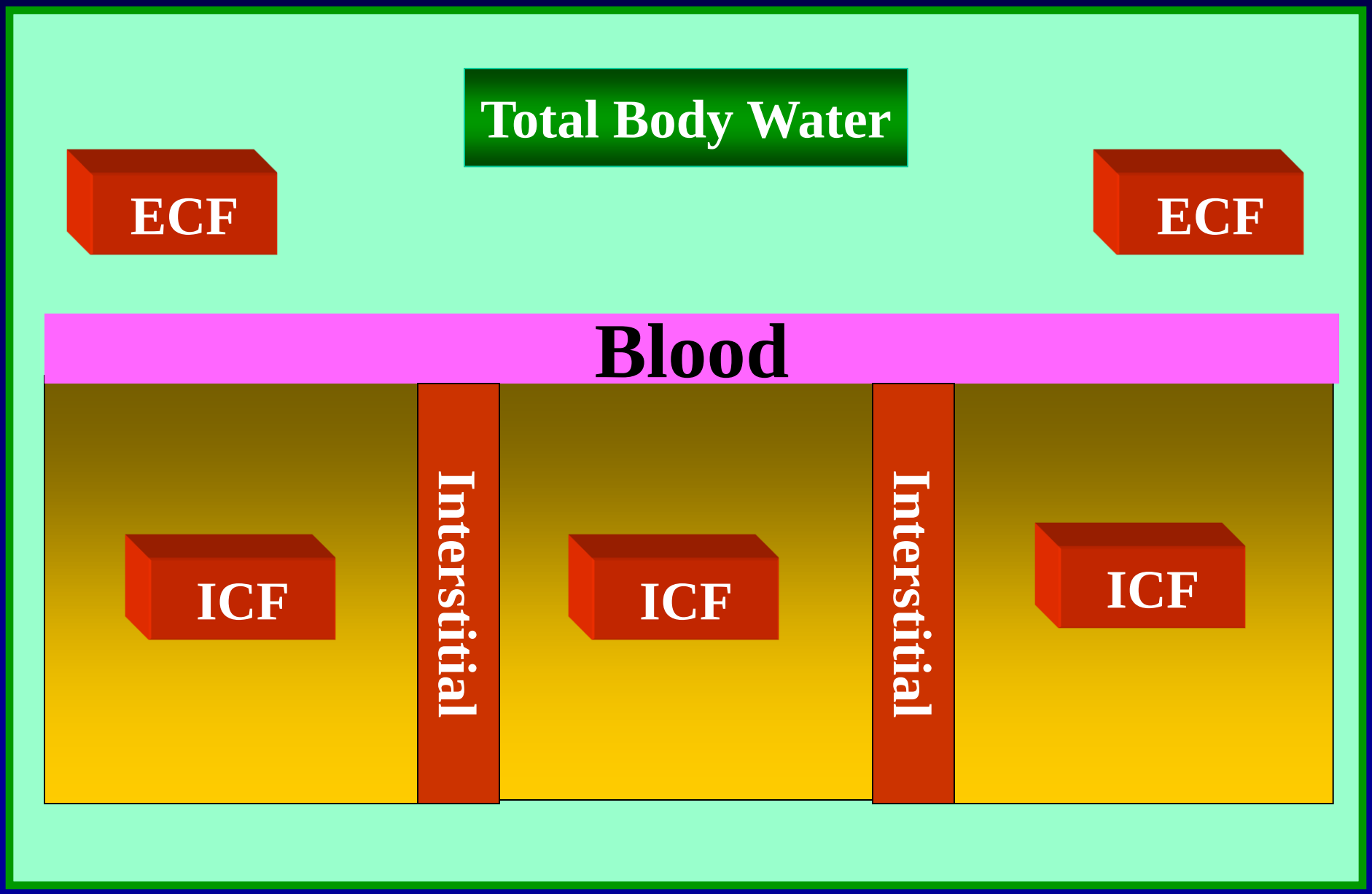
14 L(ROUGHLY 1/3 OF TBW)

INTERSTITIAL

11 L (ROUGHLY ¾ OF ECF)

PLASMA

4 L (ROUGHLY ¼ OF ECF)


Total Body Water
ECF
ECF
Blood
Interstitial
Interstitial
ICF
ICF
ICF

METHODS OF MEASUREMENTS

INDIRECT METHOD –
INDICATOR (DYE) DILUTION TECHNIQUE

- PRINCIPLE
  - **YOU HAVE TO SELECT A SUITABLE DYE OR RADIO-ISOTOPE**
- V= VOLUME OF FLUID
- A= TOTAL AMOUNT OF DYE USED
- E= AMOUNT OF DYE EXCRETED OR LOST .
- C= CONCENTRATION

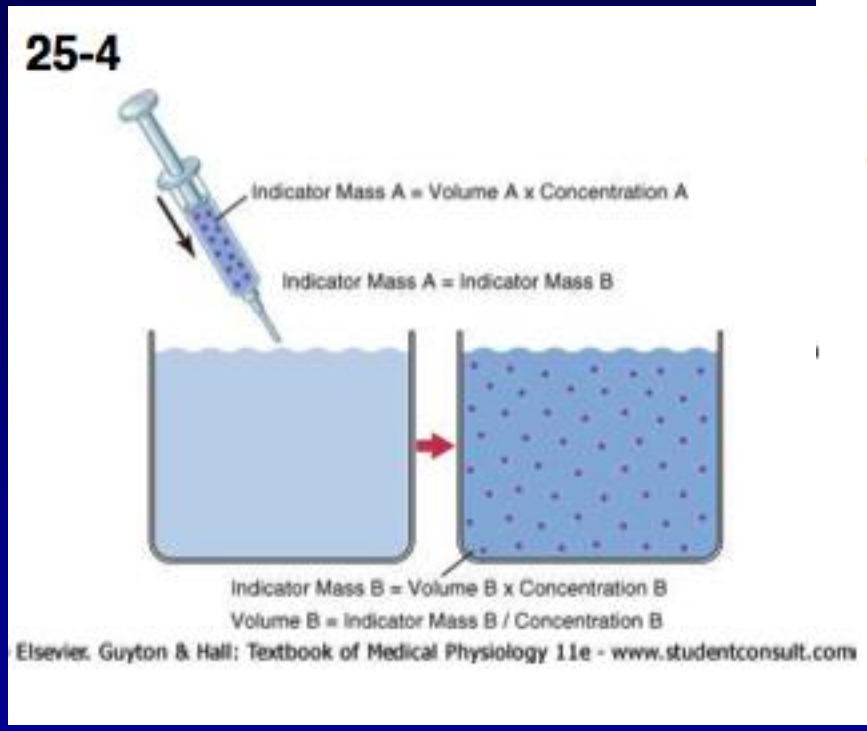
FORMULA
V=A-E/C

Calculating Compartment fluid Volume

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

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,

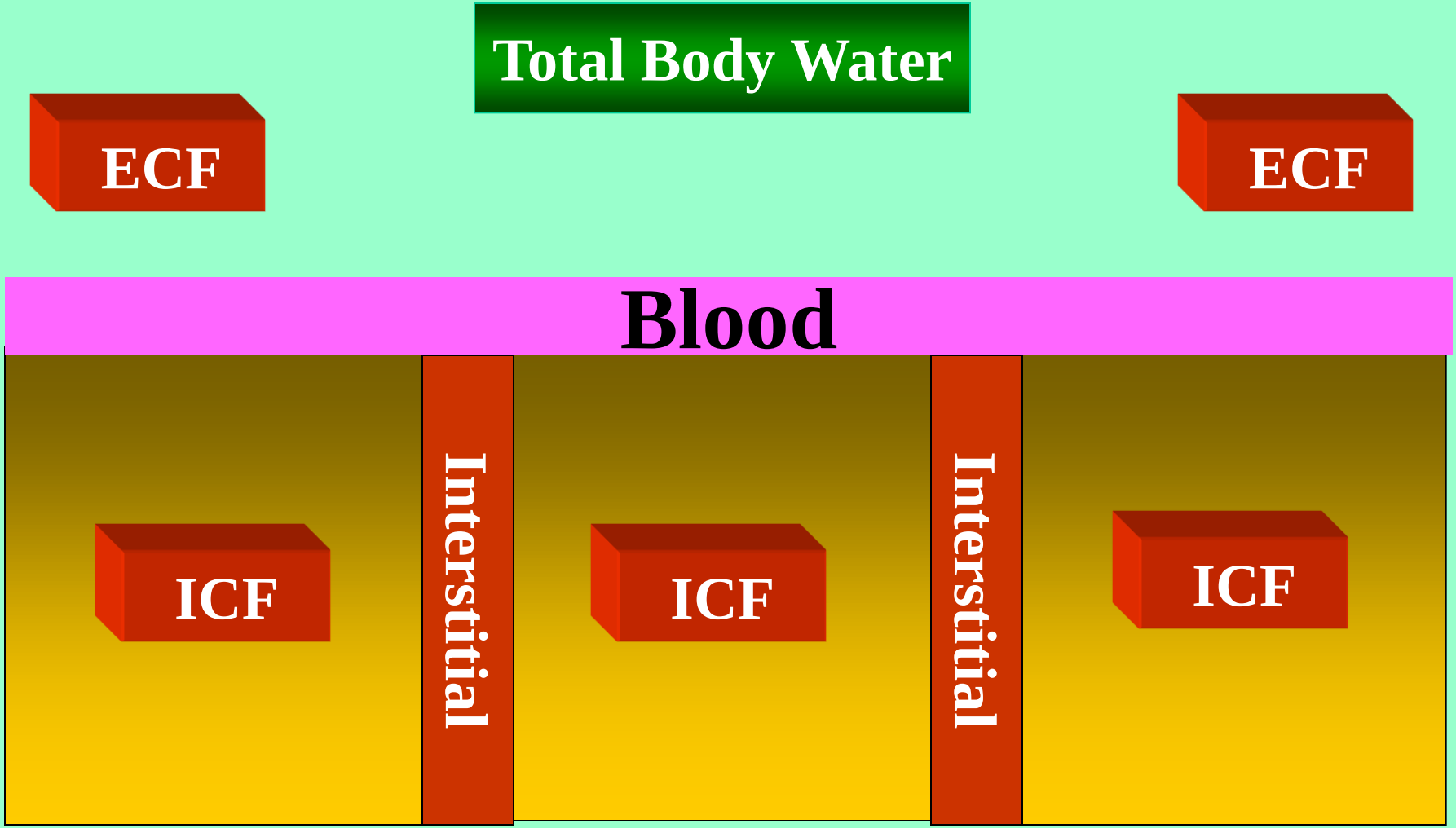
$$\text{Volume B} = \frac{1\ \text{ml} \times 10\ \text{mg/ml}}{0.01\ \text{mg/ml}} = 1000\ \text{ml}$$

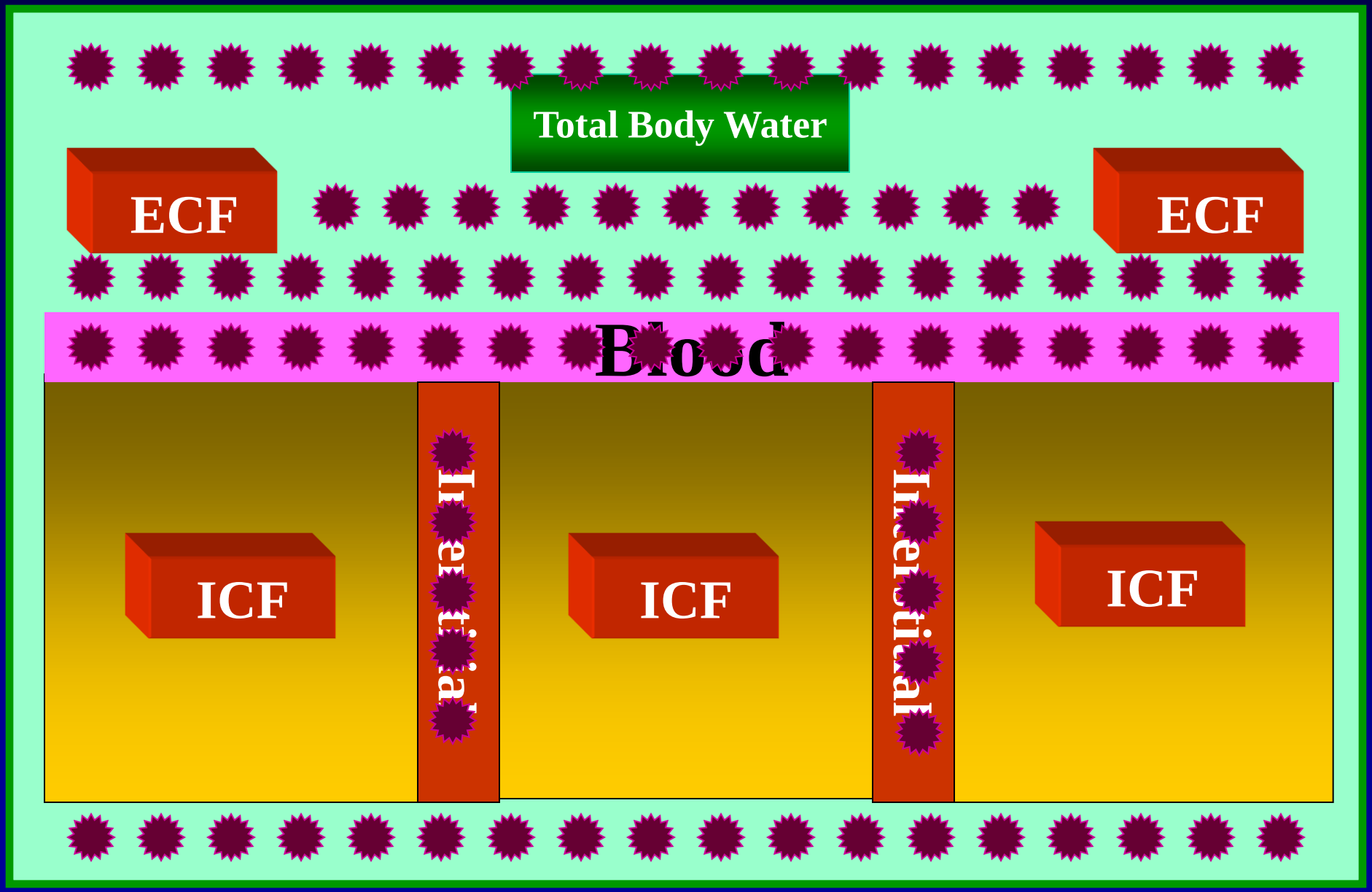


Mass & conc of indicator are known before

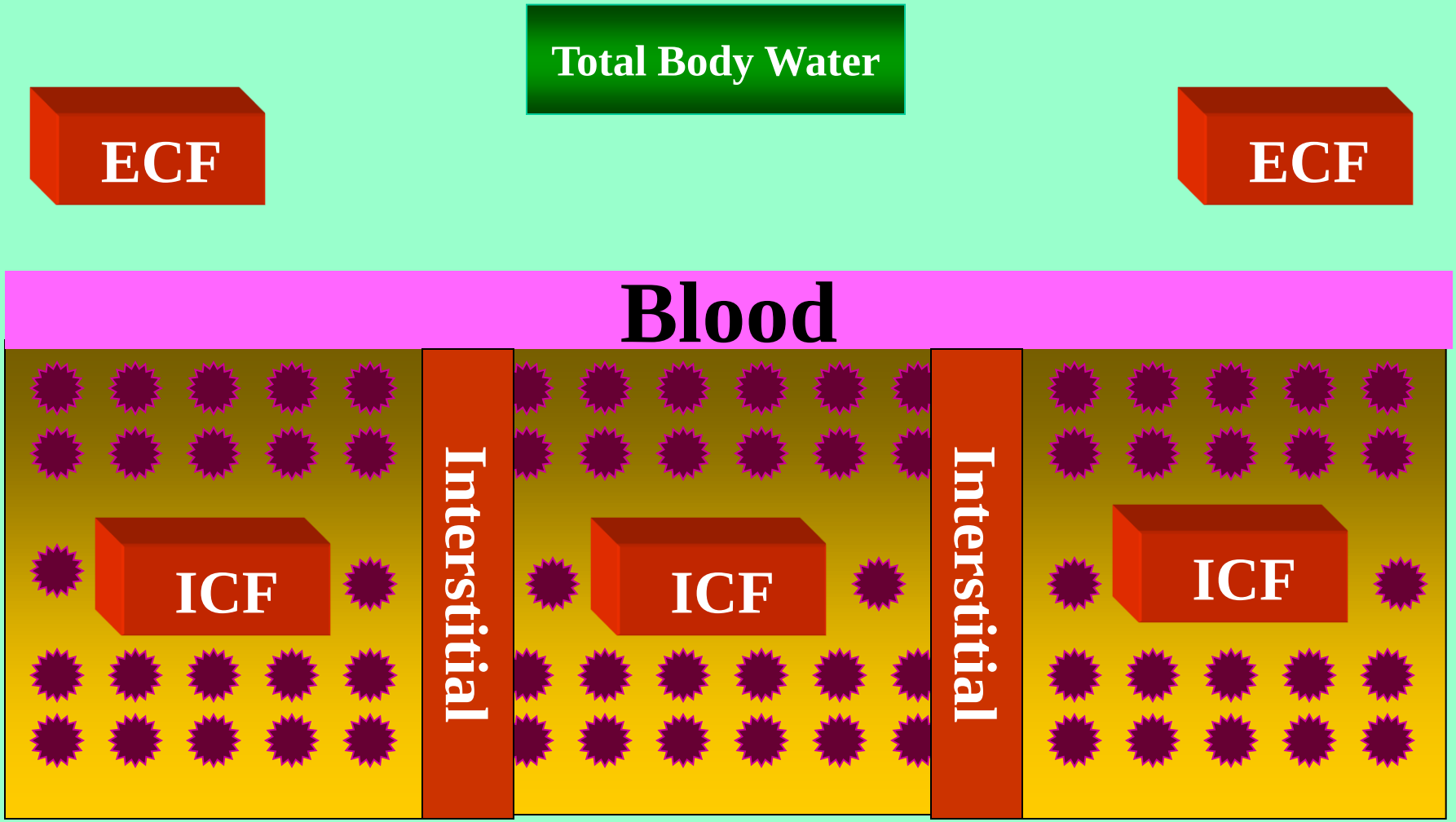
This works only if the indicator uniformly diffused and only into the measured fluid compartment, and if the indicator itself is not metabolized or excreted.

Normal


Total Body Water
ECF
ECF
Blood
Interstitial
Interstitial
ICF
ICF
ICF


Total Body Water
ECF
ECF
Blood
ICF
Interstitial
ICF
Interstitial
ICF

Dye injected




Anwar Ali Khan

VOLUME MEASUREMENT OF VARIOUS FLUID COMPARTMENTS

INTERSTITIAL FLUID

ECF – Plasma Volume

INTRACELLULAR FLUID

TBW – ECF

VOLUME MEASUREMENT OF VARIOUS FLUID COMPARTMENTS

- Dye Dilution Principle

TOTAL BODY WATER (TBW)
SUBSTANCE USED

- **Deuterium oxide (d2o)**
- **Titrated water**
- **Antipyrine**
- **Aminopyrine**

VOLUME MEASUREMENT OF VARIOUS FLUID COMPARTMENTS

- **EXTRACELLULAR FLUID**
- **substances used : two major types:**
  - **saccharides e.g. sucrose, inulin, mannitol**
  - **diffusible ions e.g. sulphate, sodium, thiosulphate, bromide, chloride**

VOLUME MEASUREMENT OF VARIOUS FLUID COMPARTMENTS

BLOOD PLASMA.

- **Evan's blue**
- **Radioactive labeled 125 i albumin**

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

- Remember, hematocrit can be measured by centrifuging in ultra centrifuge machine

CRITERIA FOR A SUITABLE DYE.

- **Must mix evenly throughout the compartment**
- **Non toxic**
- **Must have no effect of its own on the distribution of water or other substances in the body**
- **Either It Must Be Unchanged During The Experiment Or If It Changes , The Amount changed must be known.**
- **The material should be relatively easy to measure.**

FACTORS AFFECTING

- **Physiological**
  - **Adipose Tissue**
  - **Sex**
  - **Age**
- **Pathological**
  - **Dehydration**
  - **Overhydration**

Osmole

- The molecular weight of a solute, in grams, divided by the number of ions or particles into which it dissociates in solution

Sila Jangan confuse !

Osmolarity is a measure of the osmoles of solute per liter of solution. A capital letter M is used to abbreviate units of mol/L. Since the volume of solution changes with the amount of solute added as well as with changes in temperature and pressure, osmolarity is difficult to determine.

Osmolality is a measure of the moles (or osmoles) of solute per kilogram of solvent expressed as (mol/kg, molal, or *m*). Since the amount of solvent will remain constant regardless of changes in temperature and pressure, osmolality is easier to evaluate and is more commonly used, and often preferred, in practical osmometry. Most commercially available osmometers report results using osmolality units mOsm/kg.

Osmolality is more accurate than **osmolarity**, because volume varies with temperature, but weight does not.

Tonicity

Is used to describe osmolality of a solution relative to plasma

Isotonic – same - eg: 0.9% Nacl, 5% Dextrose, RL

Hypotonic- lesser - (0.45% NS)

Hypertonic- higher

Normal plasma = 290 m Osm/L

Eg: Dehydration, burns, heat stroke

ORS- solution of salts and sugars given orally

IV fluids- intravenous catheter- saline, dextrose …

-order a solution based on the particular patient's serum electrolyte values and fluid-volume balance

Gibbs–Donnan effect / Donnan effect / Donnan law

- The charged particles near a semi-permeable membrane fail to distribute evenly across the two sides of the membrane.
- Cause: is the presence of a different charged substance that is unable to pass through the membrane and thus creates an uneven electrical charge distributed
- Result: More osmotically active particles inside the cell than in interstitial fluid.
- Results in Electrical difference across cell membrane
- (A natural creation)

Donnan effect

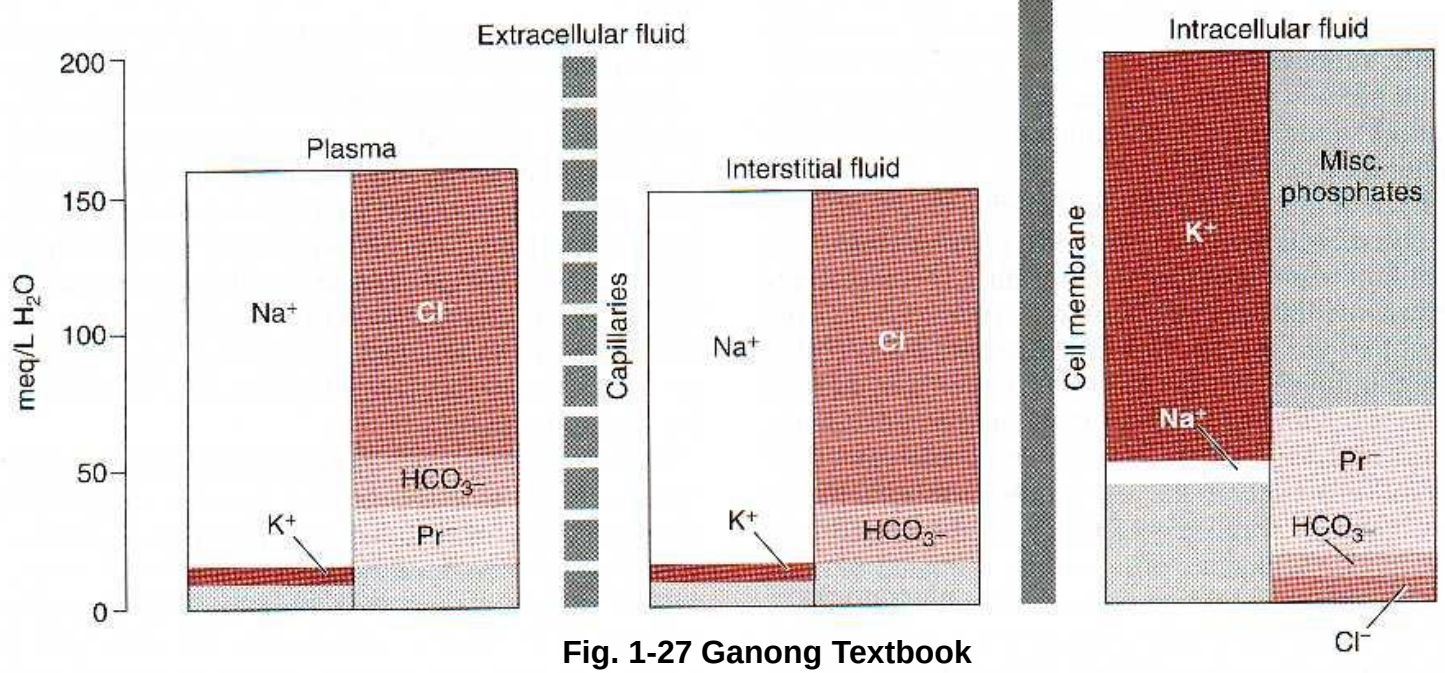
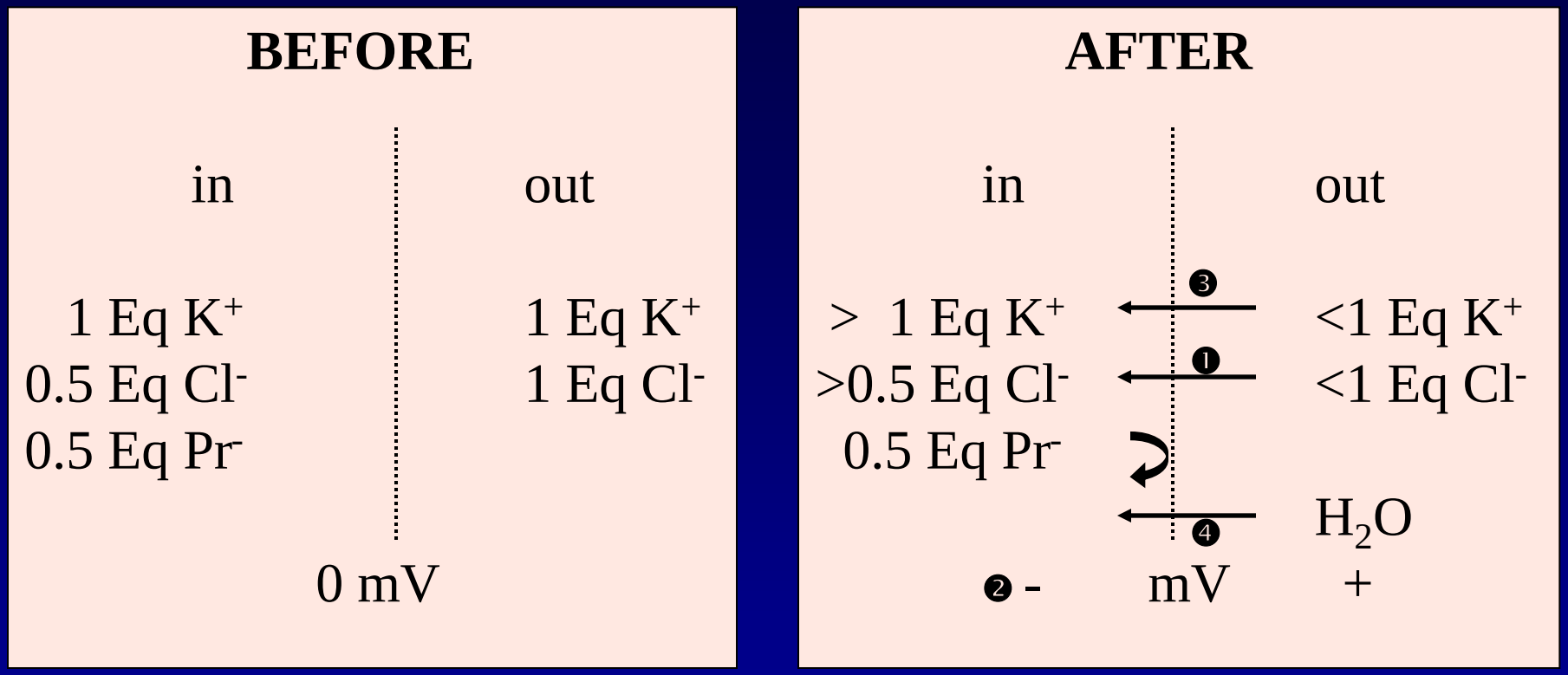


Fig. 1-27 Ganong Textbook

The Donnan Effect – simplified scenario



1. Cl^- moves in down its concentration gradient.
2. The inside of the cell becomes negative.
3. K^+ moves in down its electrical gradient.
4. By osmosis, H_2O follows the K^+ and Cl^-.

In human living cells

- The problem: Because of the Donnan effect, cells will swell and burst.
- The solution:

  Sodium potassium pump solves the problem.
  - Na^+ pumped out
  - Cl^- follows Na^+
  - H_2O follows NaCl

So cell size is restored

So balance

Living cell in Human physiology

- Na K pump: pumps 3 Na+ out and 2 K+ inside
- Physiological balance is restored as long as person is healthy.
- But in disease ?
- We have to restore balance by the help of external medications, surgeries etc….,

APPLICATION

- According to UN, nearly 40% of people in Tigray region of Ethiopia are currently suffering from lack of food to eat every day.
- How does this affect the body fluids?
- Is the homeostasis still maintained in the body?

- We cannot solve our problems with the same thinking we used when we created them **Albert Einstein**

- Every problem has a solution. Each problem that is solved becomes a rule, which serves afterwards to solve other problems. So, Effective management = effective problem solving

  Dr k

assignment - 1

- What is Donnan effect?

  Is Donnan effect hazardous? How is this prevented ?


THANKS