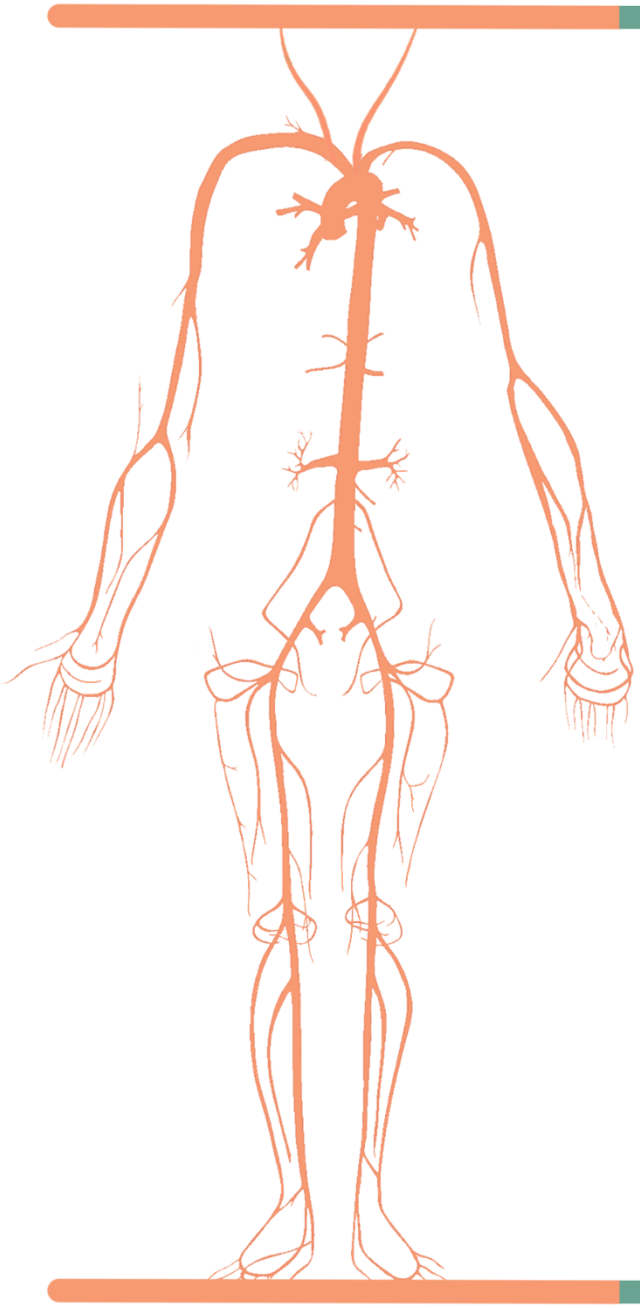
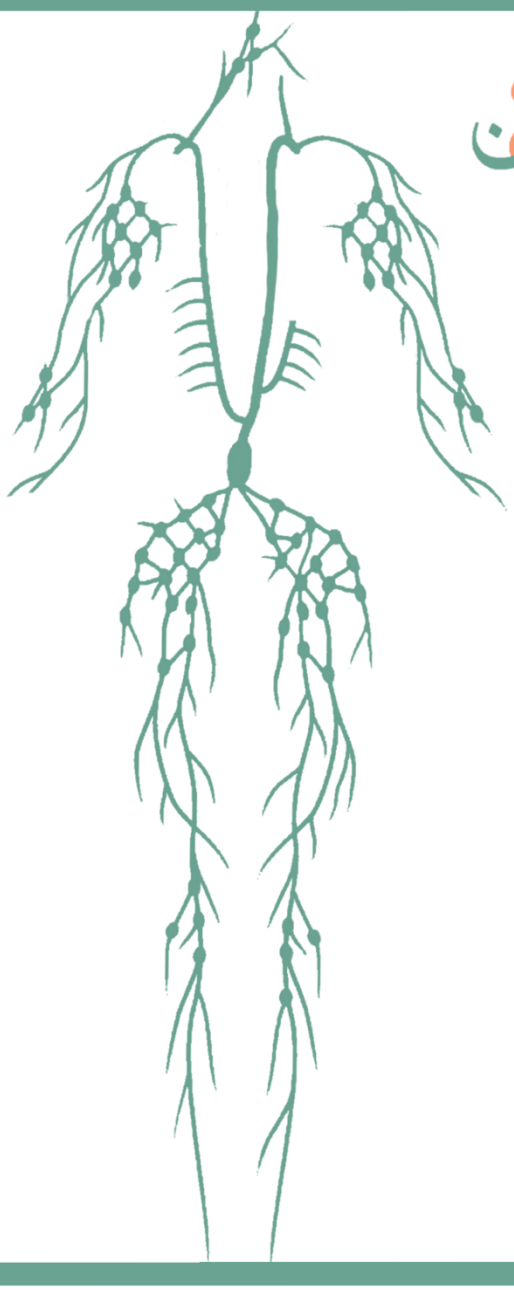
Physiology

HematoLymphatic





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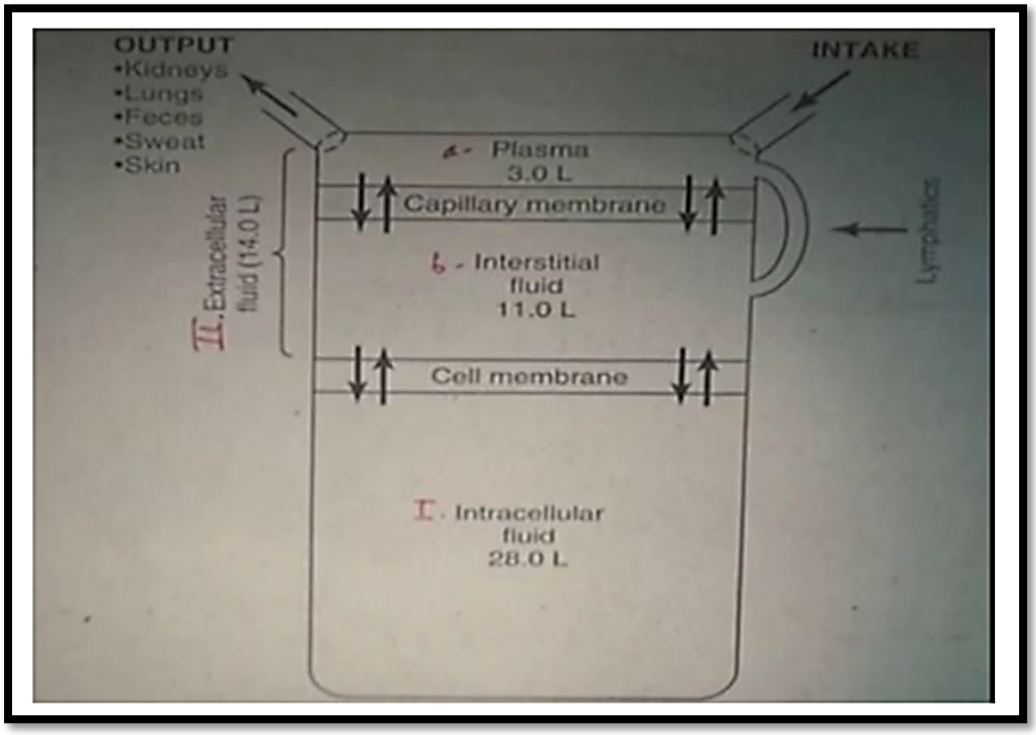
Body fluids

In 70-kg person, body fluids occupy around 42 liters .

Body fluids are presented in two compartments :-

1- Intracellular compartment, inside the cells, 28 liters
2- Extracellular compartment , outside the cells , 14 liters . Extracellular fluids are divided into :-
   A- Plasma : 3 liters
   B- Interstitial : 11 liters



The table below shows the composition of the extracellular and intracellular fluid compartments :-

COMPOSITION OF EXTRACELLULAR AND INTRACELLULAR FLUID COMPARTMENTS
(values in meq/l unless otherwise indicated)

CONSTITUENTS AND PROPERTIES	EXTRACELLULAR FLUID		INTRACELLULAR FLUID
	PLASMA	INTERSTITIAL FLUID	
Sodium	142	145	10
Potassium	4	4	160
Calcium	5	5	2
Magnesium	2	2	26
Chloride	101	114	3
Sulfate	1	1	20
Bicarbonate	27	31	10
Phosphate	2	2	100
Organic acids	6	7	—
Proteins	16	1	65
Glucose (av)	90 mg%	90 mg%	0–20 mg%
Lipids (av)	0.5 g%	—	—
pH	7.4	7.4	6.7

1- **In the extracellular compartment there is no significant difference between the plasma and the interstitial fluid concerning the concentrations of the constituents and the Ph EXCEPT for the proteins, and that's to provide colloidal osmotic pressure (ranges between 25-28 mmHg). There is a significant difference between the concentration of proteins in plasma and the concentration of proteins in the interstitial fluid.**

2- **But, when we compare the extracellular fluid and intracellular fluid we can see that the concentrations of potassium, sulfate, phosphate, and proteins are much higher inside the cells compared to their extracellular concentrations(interstitial fluid).**

3- **The concentration of sodium outside the cell is much higher than intracellularly. Whereas the concentration of potassium intracellularly is much higher than outside the cells. (note: The Na+/K+ pump has a key role in maintaining this state) .**

DISTRIBUTION OF WATER IN VARIOUS TISSUES AND ORGANS

TISSUE/ORGAN	PERCENT WATER	PERCENT BODY WEIGHT	L. IN 70 KG MAN
Skin	72.0	18.0	9.07
Muscle	75.7	41.7	22.10
Skeleton	31.0	15.9	3.45
Brain	74.8	2.0	1.05
Liver	68.3	2.3	1.10
Heart	79.2	0.5	0.28
Lungs	79.0	0.7	0.39
Kidneys	82.7	0.4	0.23
Spleen	75.8	0.2	0.11
Blood	83.0	7.7	4.47
Intestine	74.5	1.8	0.94
Adipose	10.0	9.0	0.63
Total body	62.0	100.0	43.40

The table above shows the Distribution of water in various tissues and organs .

Percent water: (% organ's content of water)

- Blood has the highest amount of water, followed by the kidneys and the Adipose tissues has the lowest amount of water

Percent to body weight (how much these organs constitute of the body weight)

- Skin (18%) , muscles (41.7 % about 42 %) and skeleton (15.9%) .

L. in 70-kg man (how many liters of water these organs contain)

- Skin (9.07 liters) , muscle (22.10 liters) and the blood (4.47 about 5 liters) .

Total body water (TBW) in relation to age and sex:-

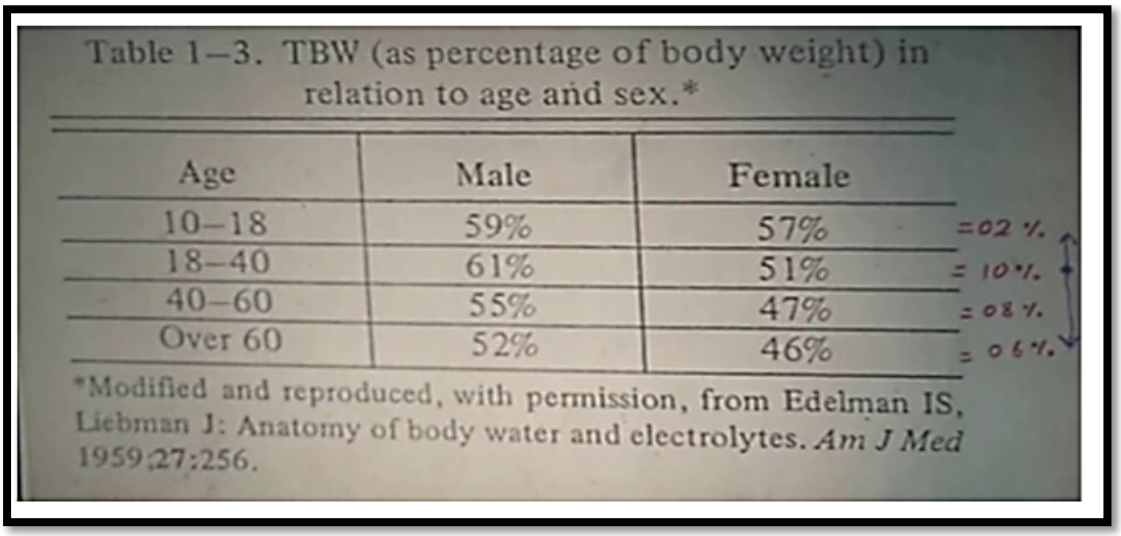


Table 1–3. TBW (as percentage of body weight) in relation to age and sex.*

Age	Male	Female	
10–18	59%	57%	=02 %
18–40	61%	51%	= 10 %
40–60	55%	47%	= 08 %
Over 60	52%	46%	= 06 %

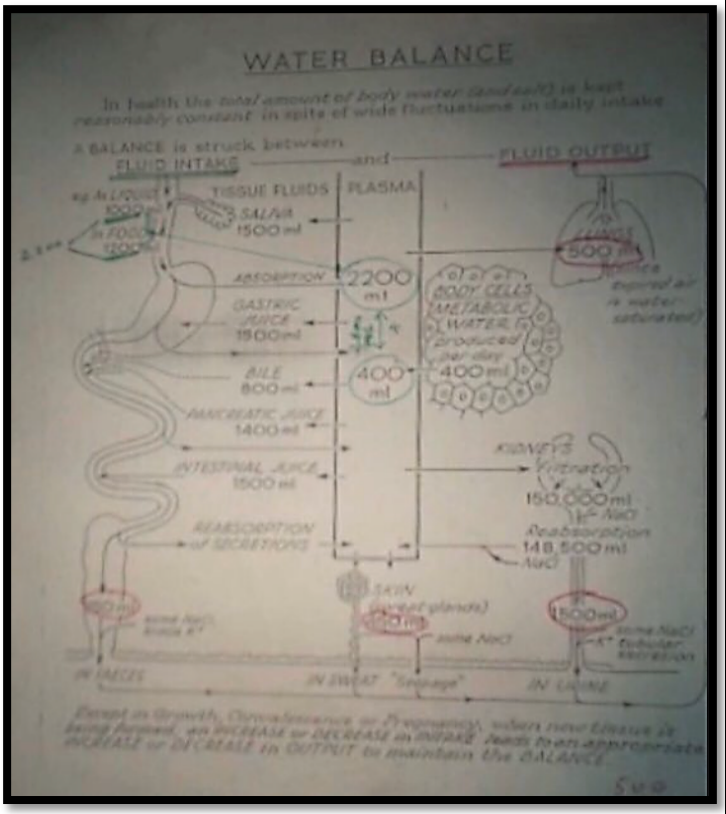
*Modified and reproduced, with permission, from Edelman IS, Liebman J: Anatomy of body water and electrolytes. *Am J Med* 1959;27:256.

1- Before the age of 18(puberty), there's almost no difference in TBW (as a percentage of body weight) between males and females.

2- Between the age of 18-40, there's a significant difference between males and females because of the effect of sex hormones. Females have a higher proportion of body fat; as a result, total body water is about 50% of their body weight, whereas about 60% of the body weight of an adult male is water.

3-After the age of 40, the difference between males and females starts to decline gradually. (Notice that the 10 % difference declines to 8% then to 6%)

Water balance



Water balance : fluid intake should be equal to the fluid output .

A- Fluid intake :-

➢ Fluid ingested as liquid: 1.0 L (1000ml)

➢ Fluid from ingested food: 1.2 L (1200ml)

➢ Fluid from metabolism: 0.4 L (400ml)

Total fluid intake = 2.6 L (2600ml)

B- Fluid output :-

➢ Through urine: 1.5 L (1500ml)

➢ through expiration(through the lungs) : 0.5 L (500ml)

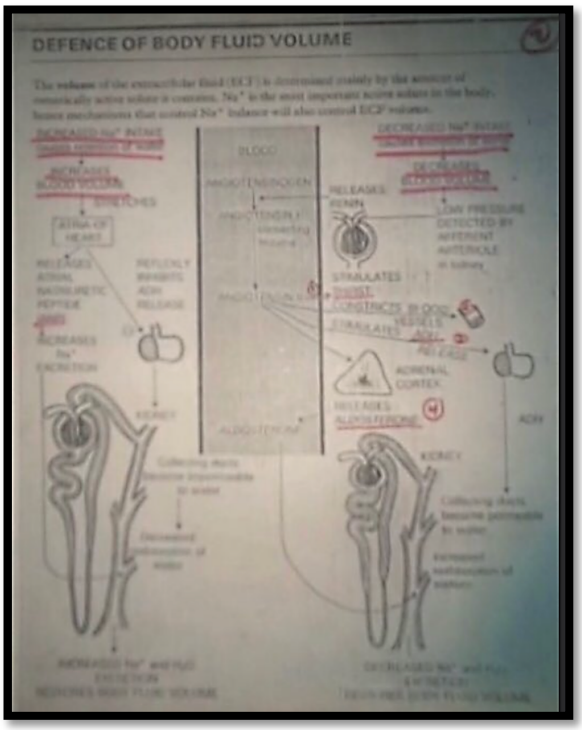
➢ through sweat glands (through the skin) : 0.45 L (450ml)

➢ through feces: 0.15 L (150ml)

Total fluid output = 2.6 L (2600)

Defense of body fluid volume :-

There are defense mechanisms against abnormalities in body fluids (excess or reduced fluid volume).



The volume of the extracellular fluid (ECF) is determined mainly by the amount of osmotically active solutes it contains . Na+ is the most important active solute in the body , hence mechanisms that control Na+ balance will also control ECF balance

A- Increased Na+ intake :-

1-causes retention of water
2-which increases blood volume
3-A hormone called “Atrial Natriuretic Peptide (ANP)” is released from the atria of the heart. This hormone increases sodium excretion.
4-Reflexly, ADH release from the posterior pituitary is inhibited ; consequently sodium and water excretion is stimulated.
5-The increased Na+ and water excretion restores normal body fluid volume.

B- Decreased sodium intake :-

1-causes excretion of water
2-which decreases the blood volume
3-low pressure detected by afferent arteriole in kidney
4-Renin (hormone) is secreted from the kidneys , this hormone will convert angiotensinogen into angiotensin I that will be converted into angiotensin II by a converting enzyme in the lungs .

Angiotensin II causes :-

- **1. Thirst .**
- **2. Constriction of blood vessels.**
- **3. Stimulation of the release of ADH.**
- **4. Stimulation of the release of aldosterone from the adrenal cortex this will lead to increased reabsorption of Na+ and water.**

4- The decreased excretion of Na+ and water restores normal body fluid volume.

Dehydration

If the hemodynamics mechanisms fail to operate properly , loss of fluid, electrolytes (ions) or both may occur .

These conditions may arise depending on the relative losses of fluid and electrolyte:-

	Isotonic dehydration	Hypertonic dehydration	Hypotonic dehydration
	Equal loss of fluid and electrolyte	**Excessive fluid loss as compared to electrolytes**	**Excessive electrolyte loss as compared to fluids**
	There is a proportionate loss of fluid and electrolyte so that the total volume of ECF changes, but its osmotic pressure remains within normal limits.	**More fluid than electrolytes is lost. As a result, the ECF becomes more concentrated. Water thus tends to be drawn from cells.**	**More solute than fluid is lost, therefore, the ECF becomes diluted. Water thus tends to enter cells.**

☺ **Clinical dehydration may be a consequence of :-**

1-failure of water absorption from the GI.

2-Excessive loss from sweating, diarrhea, vomiting or excessive diuretics.

3-diabetic patients are usually dehydrated due to excessive urination

Hydration (water intoxication).

Hydration is a term referring to the results of :-

1) Excessive water intake
2) Decreased loss of water
3) Increased reabsorption of water from the kidney because of ADH administration.

Note: excessive water is evenly distributed between extracellular and intracellular, this increased water volume causes the dilution of the substances within the extracellular and intracellular.

Excessive water intake may produce the syndrome of water intoxication in which :-

1- **Cellular function is disturbed by the dilution of cellular electrolytes .**
2- **Disorientation , convulsions and coma.**
3- **Gastrointestinal dysfunction , muscular weakness , and abnormal cardiac rhythms.**

Lymphatic system :-

1- In the arterial end the blood pressure is 32 and the colloidal osmotic pressure is 28 so filtration happens (movement of plasma containing little proteins out of the vessels to the interstitial spaces).

2 - At the Venous end the blood pressure decreases to 16 and colloidal pressure doesn't change so osmosis occurs (the substance return from the interstitial spaces to the vessels by osmosis).

3 - After osmosis little of plasma and proteins remain in the tissue these remaining go into lymphatics (the lymphatic system clears the interstitial space).

☺ The Lymphatic system represents an accessory route through which fluid can flow from the interstitial spaces into the blood :-

1- Lymph: is the fluid that flows through the lymphatic system and drains into the venous blood via the thoracic and the right lymphatic ducts.
2- It contains clotting factors and clots on standing in vitro , similar to the plasma.
3- In most locations , it also contains proteins that traverse capillary walls and return to the blood via the lymph . Its protein content is generally lower than that of the plasma , which contains about 7g/dl , but lymph protein content varies with the region from which the lymph drains .
4- Water-insoluble fats are absorbed from the intestines into the lymphatics , and the lymph in the thoracic duct after a meal is milky because of its high fat content .
5- Lymphocytes enter the circulation principally through the lymphatics , and there are appreciable number of lymphocytes in thoracic duct lymph .

☺components of the lymphatic system:-

(Lymphatic organs, Lymphatic vessels, Lymph nodes and Lymphatic ducts).

- **lymphatic related organs are :**

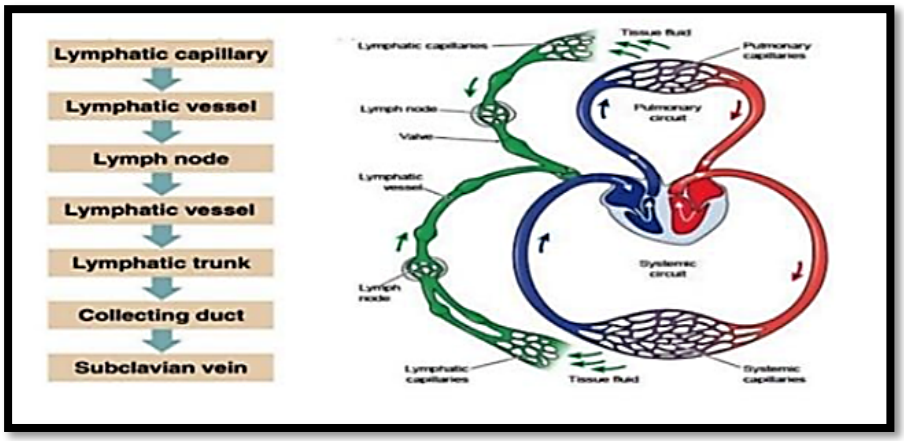
  Spleen, tonsils and thymus . All of these organs are composed largely of lymphoid tissues , a specialized form of connective tissue characterized by a framework of reticular tissue and the presence of lymphocytes .

- **Tissues that lack lymphatic capillaries :**

  Include avascular tissues (such as cartilage , the epidermis , and the cornea of the eye) , the central nervous system , portions of the spleen, and bone marrow .

- **Flow of lymph:**

Lymph, like venous blood, is under relatively low pressure and may not flow readily through the lymphatic vessels without the aid of outside forces.



☺ These forces include:-

1-Contraction of skeletal muscles.

2-Pressure changes due to the action of breathing muscles.

3-Contraction of smooth muscles in the wall of larger lymphatic vessel.

The most important functions of the lymphatic system:-

1-Return of excess filtered fluid ,
normally capillary infiltration exceeds reabsorption by about 3 liters per day (20L filtered, 17L reabsorbed). Obviously, these 3 liters must be returned to the circulating plasma, and this task is accomplished by the lymph vessels.

2-Defense against diseases : the lymph percolates through lymph nodes located on the route within the lymphatic system. The passage of this fluid through the lymph nodes is an important aspect of the body's defense mechanism against diseases. For example , bacteria picked up from interstitial fluid are destroyed by phagocytic cells in lymph nodes.

3-Transport of absorbed fat from the digestive tract.

4-Return of filtered protein, most capillaries permit leakage of some plasma proteins during filtration, these proteins cannot readily be reabsorbed back into the blood capillaries, but they can easily gain access to the lymphatic capillaries.

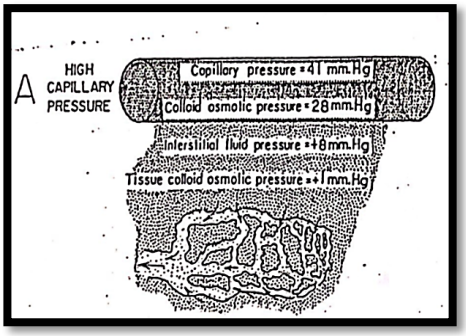
Edema

Edema is a condition caused by accumulation of fluid (as well as proteins) in the interstitial compartment.

Some factors involved in the production of edema such as :-

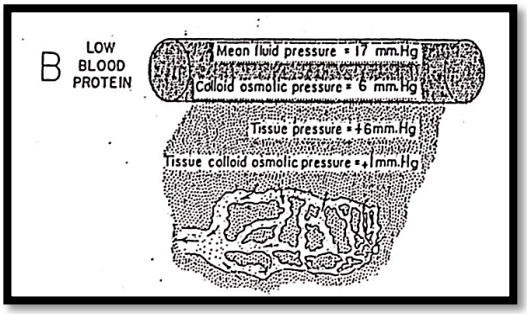
1. High capillary pressure

Higher than normal amount of fluid is filtered (from the capillaries into the interstitial spaces)
Not the whole filtered fluid will return to the capillary.



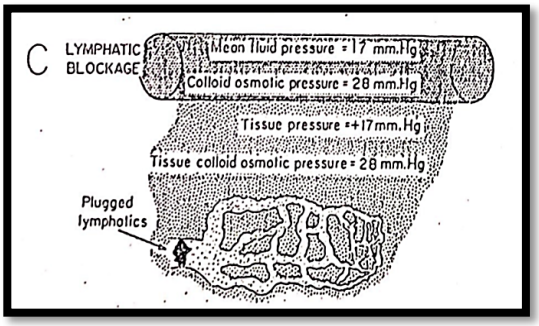
2. Low blood protein (low protein pressure/ oncotic pressure)

The low protein pressure causes less than normal amounts of fluid to return by osmosis from the interstitial spaces.



3. Lymphatic blockage

Blockage of the lymphatics prevent fluid from returning to the circulation.



4. Increased capillary porosity

(Increase in the diameter of capillary pores ; higher amount of fluid is filtered) the same consequences as in the first cause.

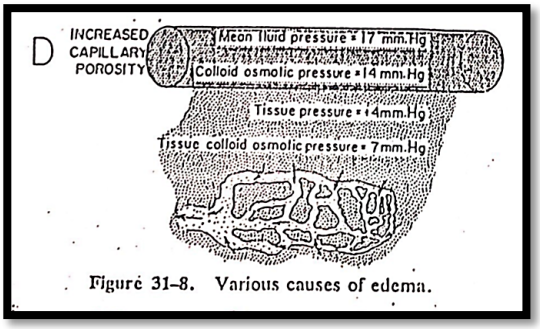


Figure 31–8. Various causes of edema.