HEMATOLOGY
&LYMPH SYSTEM

physiology sheet

Number	11
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Doctor	saleem

This sheet is exactly the same as the last year sheet the doctor didn't say anything new.
It's done by **ReemAkiely** I just added some notes.

- <u>Topic of this lecture:</u>
  - **Body Fluids; compartments and composition.**
  - **Water balance and Defense of body fluid volume.**
  - **The lymphatic system**

Body fluids

I. Major body fluid Compartments

Figure (1)

- In a 70-Kg person, body fluid constitutes about 42 liters.

- Body fluids occupy two main Compartments:

1) The **Intracellular** Compartment→holds Most of the total body Fluids (28 liters out of 42).

2) The **Extracellular** Compartment that is further divided into:

- interstitial→11 liters.
- Plasma → 3 liters.

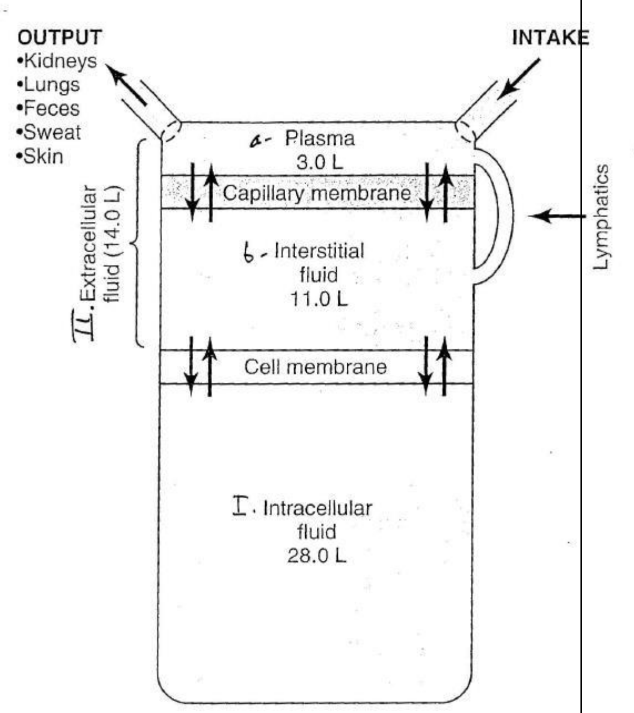


Figure 25–1

Summary of body fluid regulation, including the major body fluid compartments and the membranes that separate these compartments. The values shown are for an average 70-kilogram person.

Distribution of water in various tissues and organs

A. Water forms→83 % of blood, 82.7 % of the kidneys (the highest values)

And 10 % of adipose tissue (the lowest value)

B. Skin comprises 18 % of total body weight.

Muscle → 41.7 % of total body weight.

Skeleton → 15.9 % of total body weight.

C. Amount of water In skin →9.07 liters.

Amount of water In muscle → 22.1 liters.
Amount of water In blood →4.47 liters.

(Adipose tissue contain the lowest amount of water and the skeleton the highest)

TABLE 16.2
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

In the average 70-kilogram adult man, the total body water is about 60 percent of the body weight, or about 42 liters. This percentage can change, depending on age, gender, and degree of obesity. As a person grows older, the percentage of total body weight that is fluid gradually decreases. This is due in part to the fact that aging is usually associated with an increased percentage of the body weight being fat, which decreases the percentage of water in the body.

Because women normally have more body fat than men, their total body water averages about 50 percent of the body weight. In premature and newborn babies, the total body water ranges from 70 to 75 percent of body weight. Therefore, when discussing the "average" body fluid compartments, we should realize that variations exist, depending on age, gender, and percentage of body fat.

body fluid regulation, including the major body fluid… More »

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

Itsimportant to see the different in water percentage between male and female

- Before the age of 18, there's almost no difference in TBW (as a percentage of body weight) between males and females.
- After the age of 18, a significant difference appears between males and females because of the effects of sex hormones. (hormonal changes)

(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 of an adult male is water).

- After the age of 40, the difference between males and females starts to decline gradually. (Note that the 10 % difference in the table declined to 8% then to 6%).

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 %

Water Balance:

- The body mechanisms must maintain the concentartions of electrolytes and other elements inside and outside the cells in their normal ranges.

- The purpose of keeping body fluids normal is to keep the blood volume normal, **and consequently, maintaining the normal blood pressure.**

(The main goal is to normalize blood pressure).

- One of these body mechanisms include the Na^+/K^+ pump. Other methods are through the actions of certain hormones that will be explained in the next section.

Water balance in the body:

<u>Fluid intake = Fluid output = 2.6 L</u>

- <u>Fluid intake:</u>
  - Fluid ingested as liquid: 1 L
  - Fluid in ingested food: 1.2 L
  - Fluid from metabolism : 0.4 L

<u>Total fluid intake = 2.6 L</u>

Intake of water, however is highly variable among different people and even within the same person ON different days, depending on climate, habitsand level of physical activity

<u>Fluid output:</u>

- Through urine: 1.5 L **(**the value of fluid output through urine is changeable depending on the amount of the ingested fluid)
- Through expiration : 0.5 L
- Through sweat glands : 0.45 L (its highly variable, depending on physical activity and environmental temperature)
- Through faces: 0.15 L (can increase in people with severe diarrhea this is the reason why severe diarrhea can be life threatening if not corrected within few days)

Total fluid output = 2.6 L

Note: from the value "fluid in ingested food" (1.2 L), we can tell that the figure refers to populations of the Middle East and Asia. While in European populations, very little amount of the fluid ingested comes from food

<u>Composition of extracellular and intracellular compartments:</u>

The concentration of each substance in the plasma is similar or near to its concentration in the interstitial fluid. EXCEPT when we talk about proteins. There is a significant difference between the concentration of proteins in plasma (16 meq/L) and the concentration of proteins in the interstitial fluid (1 meq/L).

Additional piece of information:
Meq/L means milliequivalents of solutes per liter of solvent. This unit is especially common for measurement of components in biological fluids.

- The concentration of sodium outside the cell is much higher than its concentration intracellularly. Whereas the concentration of potassium intracellularly is much higher than its concentration outside the cells.

(note: The Na^+/K^+ pump has a key role in maintaining this state, and if this pump does not function properly, the human being will not survive).

- The concentrations of potassium, sulfate, phosphate, and proteins are much **higher inside the cells** compared to their extracellular concentrations.

On the other hand, the concentrations of sodium and chloride are much **higher extracellularly** compared to their intracellular concentrations.

Defense of body fluid volume:

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

A. In the case of increased body fluid volume (or " high blood volume"):

- A hormone called **"Atrial Natriuretic Peptide (ANP)"** is released from the atria of the heart. This hormone increases sodium excretion.
- Reflexly, ADH release from the posterior pituitary is inhibited sodium and water excretion is stimulated.
- The increased Na^+ and water excretion restores normal body fluid volume.

B. In the case of reduced body fluid volume

- **Renin** will be released from the kidneys. It will convert angiotensinogen into angiotensin I that will be further converted into angiotensin II by a converting enzyme.
- **Angiotensin II** is responsible for:

1. Thirst → the individual will ingest more water
2. Constriction of blood vessels
3. Stimulation of the release of ADH
4. Stimulation of the release of aldosterone from the adrenal cortex.

The previous will lead to increased reabsorption of Na^+ and water.

→The decreased excretion of Na^+ and water restores normal body fluid volume.

Dehydration:

- If the hemodynamic mechanisms fail to operate properly, loss of fluid, electrolytes (ions), or both may occur. This is called **dehydration.**
- Three conditions *(types)* may arise depending on the relative losses of fluid and electrolytes:

1) Isotonic dehydration
(Equal loss of fluid and electrolyte)
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.
2) Hypertonic dehydration
(Excessive fluid loss as compared to electrolytes)
More fluid than electrolyte is lost. As a result, the ECF becomes more concentrated. Water thus tends to be drawn from cells.
3) Hypotonic dehydration
(Excessive electrolyte loss as compared to fluids)
More solute than fluid is lost, therefore, the ECF becomes diluted. Water thus tends to enter cells.

Hydration (Water Intoxication):

- Hydration is a term referring to the results of;
    1. Excessive water intake
    2. Decreased loss of water, or
    3. Increased reabsorption of water from the kidney because of ADH administration.

(These three are the causes of hydration (or water intoxication))

- Excessive water intake may produce the syndrome of water intoxication in which cellular function is disturbed by the dilution of cellular electrolytes.
- Symptoms or consequences of water intoxication include:

<u>Disorientation, convulsions, and coma.</u>
<u>Gastrointestinal dysfunction, muscular weakness, and abnormal cardiac rhythms.</u>

Note: if alcohol is unavailable, alcohol addicts tend to drink too much water (approximately 10 L) because the result (disorientation) would be as if they got drunk due to alcohol intake.

Osmolality of plasma: (not mentioned by the doctor)

- The total osmolality of a solution is the sum of the osmolality due to each of the constituents.
- The osmolality of plasma is around 290 mOsmol/kg.
- The principle ions (Na^+, K^+, Cl^-, …, etc.)

contribute to 280 mOsmol/kg (about 96% of the osmolality of plasma).

- Glucose, amino acids, and other small non-ionic substances contribute to approximately 10 mOsmol/kg.
- Proteins contribute only around 0.5% to the total osmolality of plasma.

The Lymphatic System:

Look at *figure that* shows part of a capillary with its two ends (arterial and venous ends).

- **<u>At the arterial end:</u>**

The blood pressure is 32 mmHg **(favoring the movement outwards)**
The oncotic (plasma protein) pressure is 28 mmHg **(favoring the movement inwards)**
Net pressure = 4 mmHg (outwards)
→The net outwards pressure (4 mm Hg) at the arterial side of the capillary causes filtration (fluid and some proteins exit the capillary to the interstitial fluid).

- **<u>At the venous end:</u>**

The blood pressure is 16 mmHg (favoring the movement outwards)
**** decreased compared to the arterial end ****
The plasma protein pressure is 28 mmHg (favoring the movement inwards)
**** stays the same ****
Net pressure = 12 mmHg (inwards)
→The net inwards pressure of 12 mmHg at the venous side causes most of the lost fluid - at the arterial side – to return back to the capillary (by osmosis).

- The remaining (retained) little amount of fluid and protein that did not go back to the capillary will pass to the lymphatic vessels and this is "the lymph" (fluid and little protein that passed to the lymphatic vessels).

(Note: we said "little" because it is a small amount *relatively*, *compared to the amount that went back to the capillary*, but in reality, it's not a small amount).

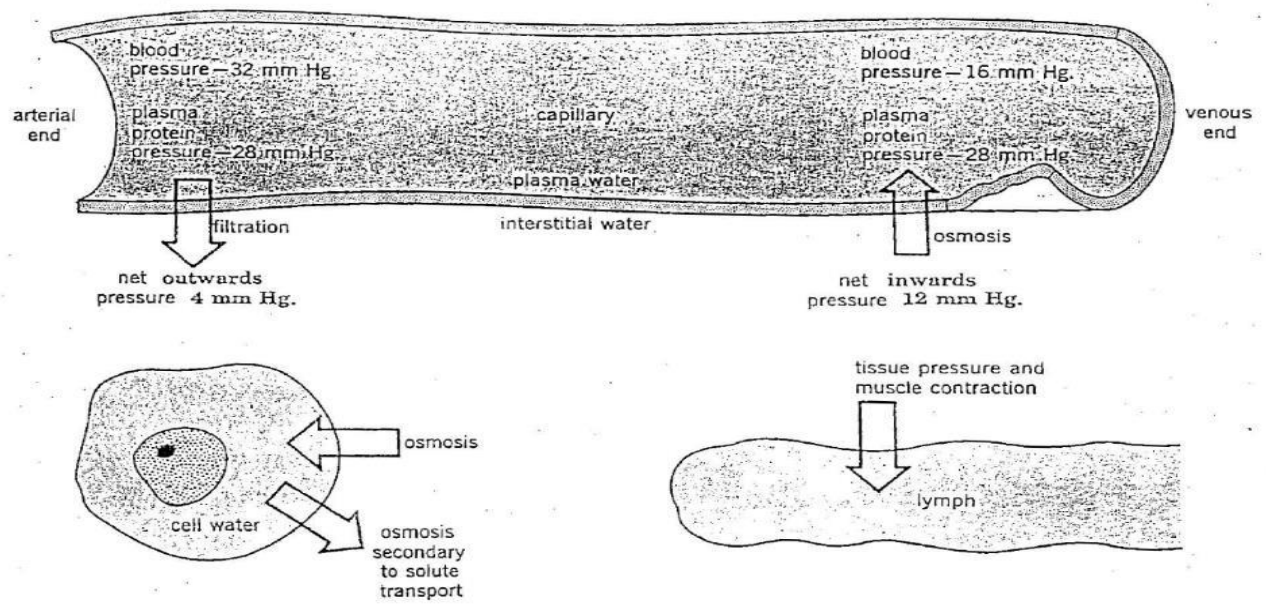


FIGURE 16.3
Some determinants of water movement between body water compartments.

<u>The lymphatic system:</u>

The lymphatic system represents an accessory route through which fluid can flow from the interstitial spaces into the blood.

1. Components of the lymphatic sys:

-Lymphatic capillaries
-Lymphatic veins
-Lymphatic nodes
-Lymphatic ducts

2. Lymph is tissue fluid that enters the lymphatic vessels. It drains into the venous blood via the **thoracic and right lymphatic ducts**.
3. . It contains clotting factors and clots on standing in vitro.

We know that plasma clots, but does the lymph clot??
Yes (Due to the **presence of clotting factors**), but coagulation of lymph is weak as a consequence of the **absence of platelets.**

4. In most locations - **and mainly in the liver-,**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 plasma, which contains about 7 g/dL, but *lymph protein content varies with the region from which the lymph drains*.

5. Water insoluble fats are absorbed from the intense into the lymphatics, and the lymph in the thoracic duct after a meal in milky because of its high fat content.

6. Lymphocytes enter the circulation principally through the lymphatics, and there are appreciable numbers of lymphocytes in the thoracic duct lymph.

The underlined words above are the answer to the question "what can we find in lymph?"

- **Note:** in the lymph nodes, there are lymphocytes that capture microbes, and usually, the microbe will not return back to the capillaries, otherwise, it would cause a disease.
- Three organs closely related to the lymphatic system are the **spleen**, **tonsils**, and **thymus**.
- Tissues that lack lymphatic capillaries include:
    1. Avascular tissues (such as cartilage, the epidermis, and the cornea of the eye)
    2. The central nervous system
    3. Portions of the spleen
    4. 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:

- Contraction of skeletal muscles
- Pressure changes due to the action of breathing muscles, and
- Contraction of smooth muscles in the wall of larger lymphatic vessels.

The most important functions of the lymphatic system:

1. Return of excess filtered fluid

2. Defense against disease

3. Transport of absorbed fat

4. Return of filtered protein

Following are the most important functions of the lymphatic system:

- *Return of Excess Filtered Fluid.* Normally, capillary filtration exceeds reabsorption by about 3 liters per day (20 liters filtered, 17 liters reabsorbed) (Fig. 8–17c). Yet the entire blood volume is only 5 liters, and only 2.75 liters of that is plasma. (Blood cells make up the remainder of the blood volume.) With an average cardiac output, 7,200 liters of blood pass through the capillaries daily under resting conditions (more when cardiac output increases). Even though only a small fraction of the filtered fluid is not reabsorbed by the blood capillaries, the cumulative effect of this process being repeated with every heartbeat results in the equivalent of more than the entire plasma volume being left behind in the interstitial fluid each day. Obviously, this fluid must be returned to the circulating plasma, and this task is accomplished by the lymph vessels. The average rate of flow through the lymph vessels is 3 liters per day, compared with 7,200 liters per day through the circulatory system.

- *Defense Against Disease.* The lymph percolates through **lymph nodes** located en route within the lymphatic system. Passage of this fluid through the lymph nodes is an important aspect of the body's defense mechanism against disease. For example, bacteria picked up from the interstitial fluid are destroyed by special phagocytic cells located within the lymph nodes.

- *Transport of Absorbed Fat.* The lymphatic system is important in the absorption of fat from the digestive tract. The end products of the digestion of dietary fats are packaged by cells lining the digestive tract into fatty particles that are too large to gain access to the blood capillaries but that can easily enter the terminal lymphatic vessels.
- *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. If the proteins were allowed to accumulate in the interstitial fluid rather than being returned to the circulation via the lymphatics, the interstitial-fluid-colloid osmotic pressure (an outward pressure) would progressively increase while the blood-colloid osmotic pressure (an inward pressure) would progressively fall. As a result, filtration forces would gradually increase and reabsorption forces would gradually decrease, resulting in progressive accumulation of fluid in the interstitial spaces at the expense of loss of plasma volume.

Edema

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

- Probable causes of edema *(figure (5))*:

1. High capillary pressure
→Higher than normal amount of fluid is filtered (normaly 32)
→Not the whole filtered blood will return back to the capillary (normally 28)
→Fluid accumulates in the interstitial spaces causing edema

2. Low blood protein (low protein pressure)
→The low protein pressure causes less than normal amounts of fluid to return back by osmosis from the interstitial spaces
→Fluid accumulates in the interstitial spaces causing edema

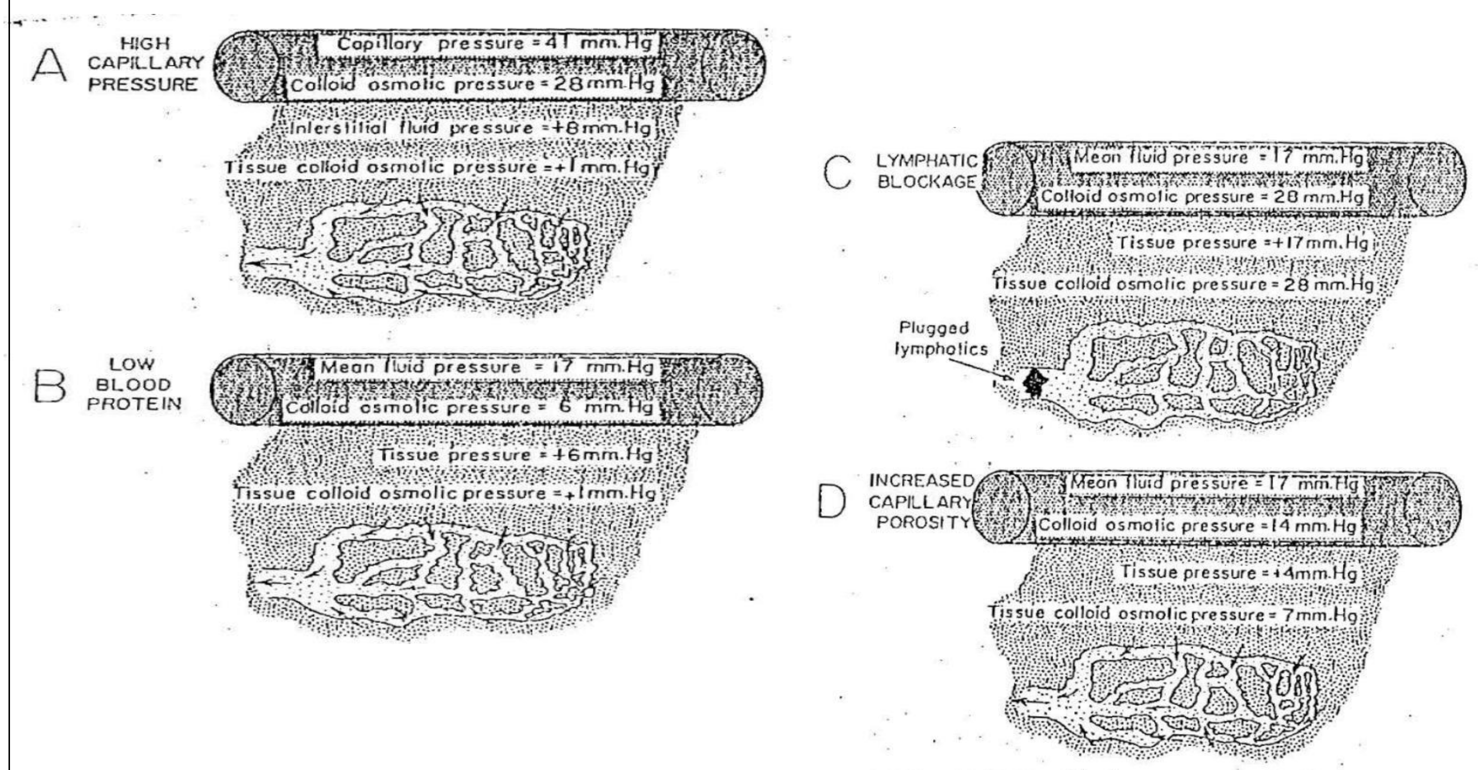
3. Lymphatic blockage

Some parasites can block lymphatics and thus prevent fluid from returning back to the circulation.

4. Increased capillary porosity

(Increase in the diameter of capillary pores)

Same consequences as in the first cause.



Hints table	
Phenotype	**genotype**
A B AB O	AA or AO BB or BO AB OO
NN MM MN	NN MM MN
Rh (positive) rh (negative)	RhRh or Rhrh rhrh

(Not mentioned by the doctor)

Problems related to blood groups and their inheritance

I. A child's blood type is "O NNrh". His mother's blood type is "A MN Rh".
a man with a blood type of "A NN Rh" is suspected to be the father. Is it possible for this man to actually be the father of the child or not?

The first step is to write down the phenotypes (of the child, his mother, and the man) and the probable genotypes.

	The man	**The mother**	**The child**
Phenotype	A NN Rh	A MN Rh	O NN rh
Probabilities of **the Genotype**	AA NN RhRh AO NN RhRh AA NN Rhrh AO NNRhrh	AA MN RhRh AO MN RhRh AA MN Rhrh AO MN Rhrh	OO NN rhrh

If we look at the child's Genotype, we can conclude that the two gametes that resulted in this genotype carried the following genes:
ONrh (on the first gamete) &ONrh (on the second gamete)
One of these two is from the mother, the second is from the father. When the paternal gamete fertilizes the maternal one, the child's genotype (OONNrhrh) will result.

 If we look at the last probable genotype in each of the second and third columns, we'll find out that these two genotypes together could have been what resulted in the child's genotype, because:

- The possible combinations of gametes resulting from the genotype AO MN Rhrh of the mother include ONrh
- The possible combinations of gametes resulting from the genotype AO NNRhrh of the man also include ONrh, meaning that this man could actually be the father of the child

II. A man with "B MM rh" blood type got married to a woman with "AB NN Rh" blood type.
A) Write down the possible genotypes that could have resulted in the phenotypes of the male and the female.
B) Write down the possible combinations of gametes resulting from each genotype you wrote in part A).

	The men	**The women**
Phenotype	B MM rh	AB NN Rh
Probabilities of **the Genotype** ***(and in italic, the possible combinations of the gametes for each genotype)***	1. BB MM rhrh • BMrh • BMrh 2. BO MM rh rh • BMrh • OMrh	1. AB NN RhRh • ANRh • BNRh 2. AB NN Rhrh • ANRh • ANrh • BNRh • BNrh