Physiological system of blood. Functional importance of blood plasma components.

BLOOD

- Blood volume is 8% of body weight
- Average adult has 5 liters of blood:

The **blood volume of an adult correlates with** his or her (fat-free) body mass and amounts to 4–4.5 L in women and 4.5–5 L in men of 70 kg BW.

- Blood, lymph and interstitial fluid are components of internal environment of the organism.
- Properties of blood as a specific tissue:

a) fluid;

b) circulated;

c) all components of the blood are performed and destroyed in special organs (but do not in blood itself).

Blood executes all transport functions: transport of gases (O_2, CO_2), nutritious, heat, hormones, defensive substances.

PHYSICO-CHEMICAL PROPERTIES OF BLOOD

1. **Composition of the blood:** plasma and formed elements: erythrocytes, leucocytes, platelets.

Plasma constitutes 55 – 60% of the volume of the blood. Formed elements constitute 40 – 45%.

99% are red blood cells, remainder white blood cells and blood platelets

- HAEMATOCRIT – special graduate capillary tube for centrifugation of the blood sample using to separate plasma and formed elements.

The **hematocrit** is an indicator of anemia, polycythemia, and other conditions.

hematocrit (cell volume/ blood volume):

in males – 0.40–0.54; in females: 0.37–0.47

2. AMOUNT OF BLOOD.

- The total amount of the blood of the body is form 6 – 7,5% of the body weight.

- It is determined by *indicator dilution method* (a colloid dye may be used to determine volume of plasma or radioactive phosphorus may be used to determine volume of erythrocytes).

3. VISCOSITY.

- If the viscosity of water is 1 unit the viscosity of blood plasma is about 2 units and the viscosity of whole blood 5 units. Therefore viscosity depends of concentration of plasma proteins and haemotocrit.

- The specific gravity of whole blood is 1.050 to 1.060.

4. COMPOSITION OF BLOOD PLASMA:

- water – 92%;
- proteins – 7-8% (albumin – 4.5%, globulin – 2-3.5%, fibrinogen – 0.4%);
- mineral substances – 0.9%;
- glucose – 4.4-6.6 mmol/L.

5. SIGNIFICANCE OF MINERAL SUBSTANCES:

a) they provide normal osmotic pressure;

b) they are components of buffer systems;

- individual ions provide normal excitability of cells (K, Na, Ca, Cl), contractile and secretary functions (Ca, Mg).

6. OSMOTIC PRESSURE.

Osmosis is the net diffusion of water from a region of high water concentration to one of lower concentration (through the cell membrane).

Osmotic pressure is equal to the amount of hydrostatic pressure that must be applied to prevent the net diffusion of water through the semipermeable membrane. The osmotic pressure of blood can be measured by osmometer or by the cryoscopic method (measuring blood freezing point that is lower of zero to 0.56 – 0.58◦C). This parameter is called "depression of the blood".

Osmotic pressure of human blood corresponds to 7.6 atm.

- OSMOTIC PRESSURE is important for regulation of water exchange between intracellular and extracellular spaces. These spaces are separated by a selective cell membrane, which is highly permeable to water but not to most of the electrolytes. Composition of intra- and extracellular fluid is different (intracellular fluid contains only small amount of Na, Cl, Ca; large amount of K, phosphates, some amount of Mg, SO_4; large amount of proteins). Osmotic pressure of all body cells is the same as that of the extracellular fluid and blood plasma (because of each diffusion of water).

- Immersion of erythrocytes in a solution of NaCl of higher concentration than blood plasma (hypertonic solution) shows that cells loss water and shrink.

- Immersion of erythrocytes in a solution of NaCl of lower concentration than blood plasma (hypotonic solution) shows that cells increase in volume (swell) and finally be disrupted (osmotic haemolysis).

- The excretory organs (kidneys, sweat glands), maintain *constant level of osmotic pressure*.

INTRACELLULAR EDEMA:

- Depression of the cell metabolic systems (hypoxia, acidosis) – depression of ion pumps – excess Na-ions inside the cell – osmosis of water into the cell – swell and death of tissues.

- Inflammation – increases cell membrane permeability – diffusion of Na-ions (and other ions) inside the cell – osmosis of water into the cell – swell and death of tissues.

7. BLOOD pH.

- Active reaction of blood (pH) depends of concentration of hydrogen (H+) hydroxyl (OH-) ions. It is parameter of extremely great importance (since metabolism normally occurs only at a definite reaction).

- pH index of arterial blood is 7.4;

- pH index of venous blood is 7.35 (owing to the large content of CO_2).

- Limits of blood pH change (compatible with life) are 6.8 to 8.0. However a persistent shift of the normal pH of 0.1 or 0.2 can be fatal too.

- Constant level of pH is maintained by

(a) the buffer systems of the tissues, blood plasma and erythrocytes (that connect hydrogen and hydroxyl ions) and

(b) the activity of the excretory organs (that eliminate hydrogen and hydroxyl ions from the organism).

There are three primary systems that regulate pH to prevent acidosis and alkalosis:

- The chemical acid-base buffer systems, which act within a fraction of a second;
- The respiratory center, which regulates the removal of CO_2 (and therefore H_2CO_3). This mechanism acts within a few minutes. It is the second line of defense.
- Kidneys, which can excrete either acid or alkaline urine. This mechanism is the slowest but the most powerful of acid-base regulatory systems. It acts within hours to several days. It is the third line of defense.

BUFFER SYSTEMS OF BLOOD AND TISSUES

1. *Bicarbonate buffer system (H_2CO_3 and $NaHCO_3$).*

This is extracellular buffer system (buffer system of the blood).

$H_2CO_3 + NaOH = NaHCO_3 + H_2O$

$NaHCO_3 + HCl = H_2CO_3 + NaCl$

- Kidneys eliminate excess of the sodium bicarbonate;
- Lungs eliminate CO_2 ($H_2CO_3 = H_2O + CO_2$).

BUFFER SYSTEMS OF BLOOD AND TISSUES

2. Phosphate buffer system (NaH_2PO_4 and Na_2HPO_4).

This is intracellular buffer system, renal tubular fluid buffer system and buffer system of the blood plasma.

$NaH_2PO_4 + NaOH = Na_2HPO_4 + H_2O$

$Na_2HPO_4 + HCl = NaH_2PO_4 + NaCl$

- Kidneys eliminate excess of sodium hydrophosphate or sodium dihydrophosphate.

BUFFER SYSTEMS OF BLOOD AND TISSUES

3. Hemoglobin buffer system (HHb and $KHHbO_2$).

This is buffer system of the erythrocytes.

$KHHbO_2 + H_2CO_3 = HHb + KHCO_3 + O_2$

- This is most powerful buffer system of the blood.

BUFFER SYSTEMS OF BLOOD AND TISSUES

4. Protein buffer system.

- This is intracellular buffer system and buffer system of the blood plasma.

8. PLASMA COLLOID OSMOTIC PRESSURE (ONCOTIC PRESSURE)

- Plasma proteins create only 1/200 part of total osmotic pressure (about 28 mm Hg). It is called oncotic pressure.
- The proteins are the only substances in the plasma that do not diffuse through the capillary membrane (small amount of proteins do diffuse into the interstitial fluid but are soon removed from this space by way of the lymph vessels). The most amounts of plasma protein remain in capillaries and keep large amount of water.
- Proteins: 7-8 mg/mL in the plasma (oncotic pressure 28 mm Hg);
- 2-3 mg/mL in the interstitial fluid (oncotic pressure 8 mm Hg);
- 0.5 per cent of the plasma in the flowing blood filters out through the capillary wall. There are more filtration of fluid into the interstitial space than reabsorbtion.

ANALYSIS OF THE FORCE CAUSING FILTRATION AT THE ARTERIAL END OF THE CAPILLARY:

Force tending to move fluid outward:		Force tending to move fluid inward:
Capillary blood pressure	**30 mm Hg**	**Plasma oncotic pressure**
Negative interstitial pressure	**3 mm Hg**	
Interstitial oncotic pressure	**8 mm Hg**	
Total outward force	**41 mm Hg**	**28 mm Hg**
Summation of force:		
Outward 41 mm Hg		
Inward 28 mm Hg		
NET OUTWARD FORCE 13 mm Hg		

ANALYSIS OF THE FORCE CAUSING REABSORPTION AT THE ARTERIAL END OF THE CAPILLARY:

Force tending to move fluid outward:		Force tending to move fluid inward:
Capillary blood pressure	**10 mm Hg**	**Plasma oncotic pressure**
Negative interstitial pressure	**3 mm Hg**	
Interstitial oncotic pressure	**8 mm Hg**	
Total outward force	**21 mm Hg**	**28 mm Hg**
Summation of force:		
Outward 21 mm Hg		
Inward 28 mm Hg		
NET OUTWARD FORCE 7 mm Hg		

EXTRACELLULAR EDEMA:

- ***Increase capillary blood pressure***.

1. Excessive kidney retention of salt and water:
a) acute or chronic kidney failure;
b) mineralocorticoid excess.

2. High venous pressure:
a) heart failure;
b) venous obstruction;
c) failure of venous pumps (paralysis of skeletal muscles; immobilized part of body; failure of venous valves).

3. Decrease arteriolar resistance:
a) excessive body heat;
b) insufficiency of sympathetic nervous system;
c) vasodilator drugs.

EXTRACELLULAR EDEMA:

- ***Decrease plasma proteins.***

1. Loss of proteins in urine (nephritic syndrome).

2. Loss of proteins from denuded skin areas (burns, wounds).

3. Failure to produce proteins:

a) liver diseases;

b) serious protein or caloric malnutrition.

4. Starvation.

EXTRACELLULAR EDEMA:

- ***Increased capillary permeability***.

1. Immune reactions (histamine).
2. Toxins or bacterial infections.
3. Vitamin deficiency (vit. C).
4. Prolong ischemia.
5. Burns.

EXTRACELLULAR EDEMA:

- ***Blockage of lymph returns.***

- Cancer.
- Infection (filaria nematodes).
- Surgery.
- Abnomality of lymphatic vessels.

Red Blood Synthesis and Aging

- Erythrocytes or RBC are synthesized in response to **erythropoetin** (kidney hormone)
- The **mature cells lack nuclei** and are small, biconcave disks. They no longer can divide.
- Cells consist 1/3 of **hemoglobin (Hb)**, the protein that carries **oxygen** in blood.
- RBC lack mitochondria and produce ATP through glycolysis only.

Red Blood Cell Destruction

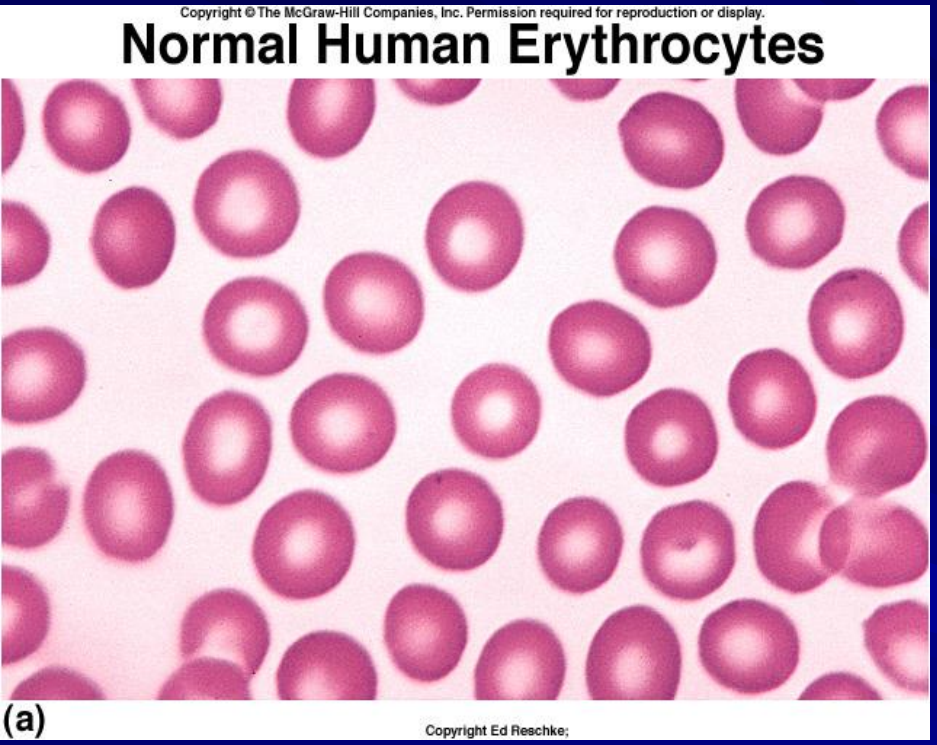
- Damaged or **worn cells rupture** in the spleen or liver.
- In the spleen or liver, **macrophages** phagocytize and destroy cells.
- **Hb** is broken down into **globin and heme** which decomposes into **biliverdin**.
- The **heme group** has a central **iron** element to which oxygen binds.
- Biliverdin is converted to **bilirubin** and excreted in **bile** via the **gallbladder**.
- **Iron** is carried on transferrin to the liver were it is stored as ferritin.

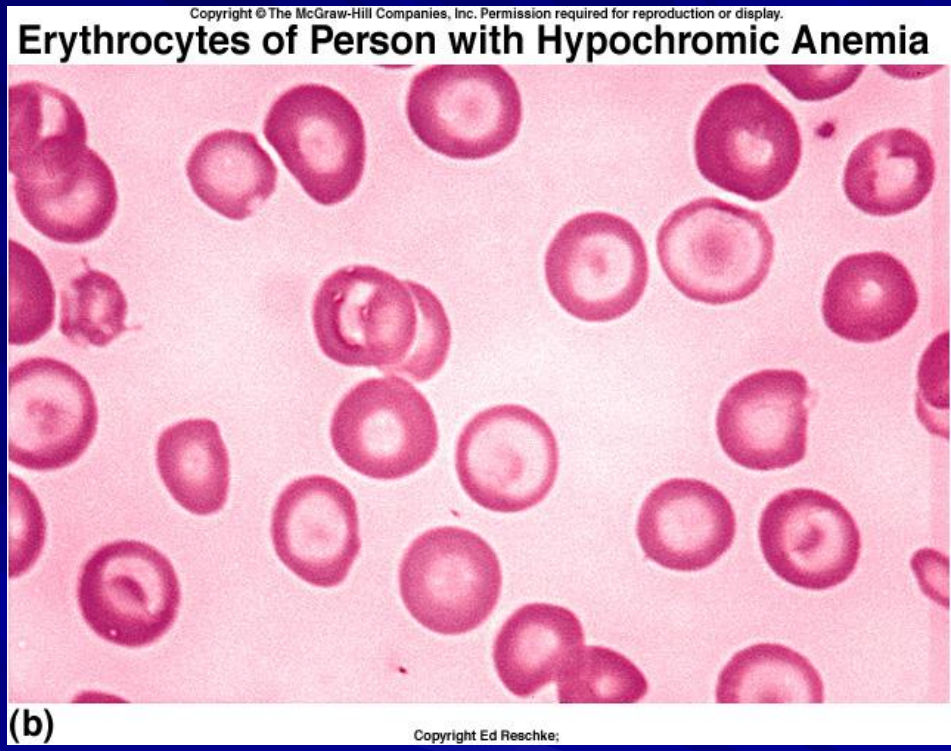
Erythropoiesis – RBC production

- Red blood cells (RBC) are called erythrocytes.
- They are produced in **red bone marrow.**
- Average life span is 120 days.
- When **oxygen concentrations in the blood are low**, erythropoietin is released from the **kidney**.
- Erythropoietin operates in a negative feedback mechanism to maintain RBC **homeostasis.**

NORMAL BLOOD

ANEMIC BLOOD





anemia: a condition in which the blood is deficient in red blood cells, in hemoglobin, or in total volume – see APLASTIC ANEMIA, HYPERCHROMIC ANEMIA, HYPOCHROMIC ANEMIA, MEGALOBLASTIC ANEMIA, MICROCYTIC ANEMIA, PERNICIOUS ANEMIA, SICKLE-CELL ANEMIA; compare OLIGOCYTHEMIA

Blood Platelets

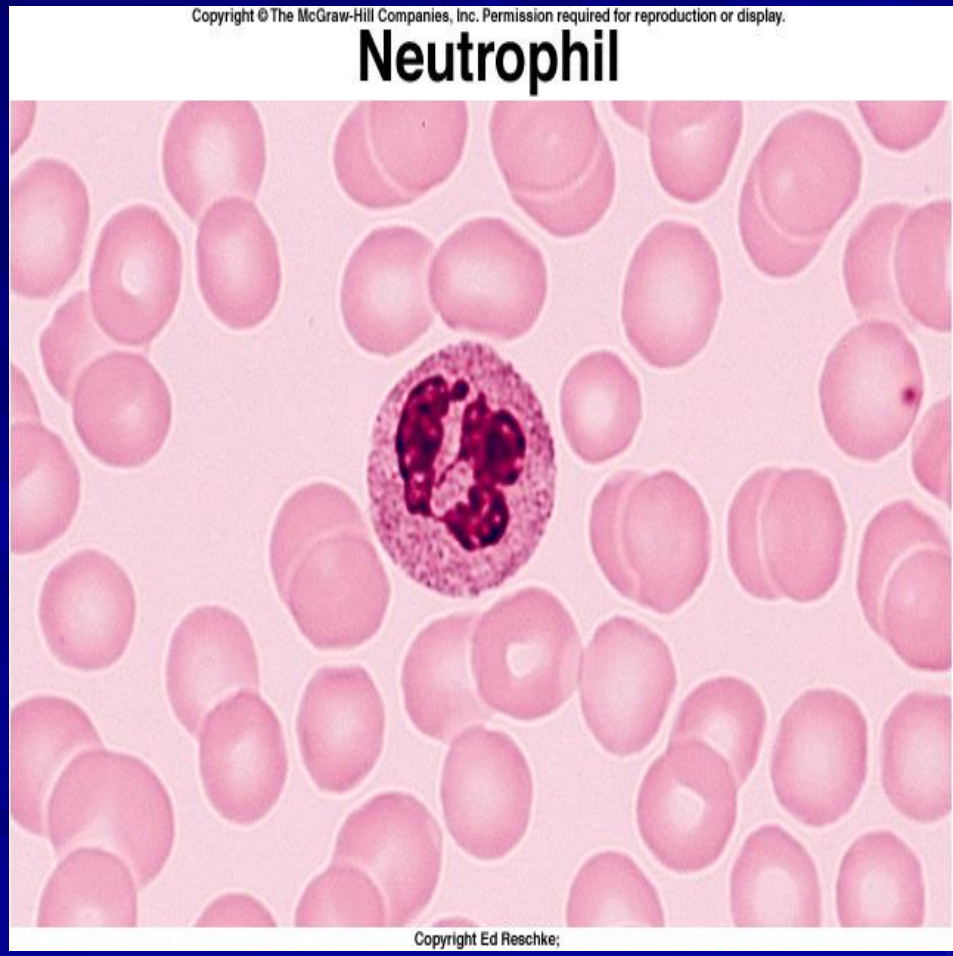
- **Thrombocytes**
- Arise from **megakaryocytes** in the red bone marrow
- Platelets are small and lack a nucleus
- Help repair broken blood vessels
- Release **serotonin**

White Blood Cells

- White Blood Cells (WBC) are called **leukocytes**.
- They protect against disease.
- **Granulocytes:** granular cytoplasm; neutrophils, eosinophils, basophils
- **Agranulocytes:** lack cytoplasmic granules; monocytes, lymphocytes

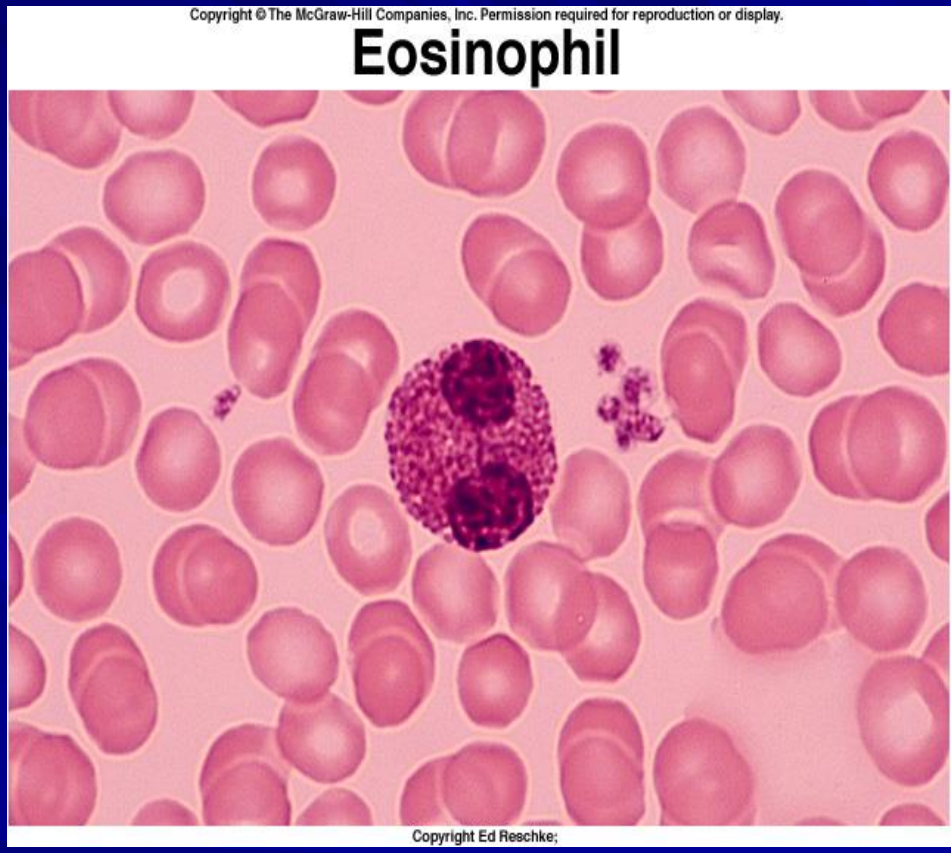
Neutrophils

- Granules stain light purple in acid-base combination stains
- First white blood cells that arrive at place of infection
- They constitute 54% to 62% of the leukocytes.
- Older neutrophils are called segs (segments) or **polymorph nuclear leukocytes** due to nuclear appearance
- Younger neutrophils are called bands



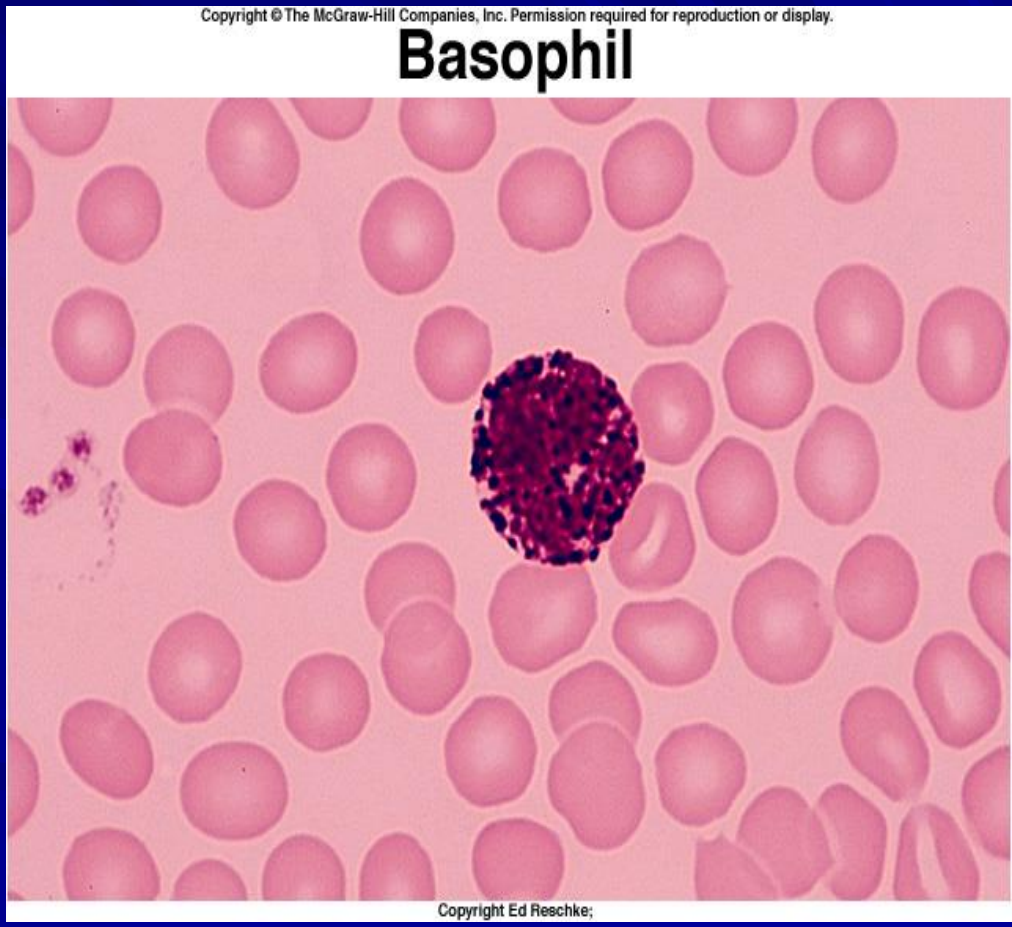
Eosinophils

- Contain coarse deep red staining granules
- Nucleus has two lobes
- Active during moderate allergic reactions
- Defend against parasitic worm infection
- Constitute 1% to 3% of leukocytes

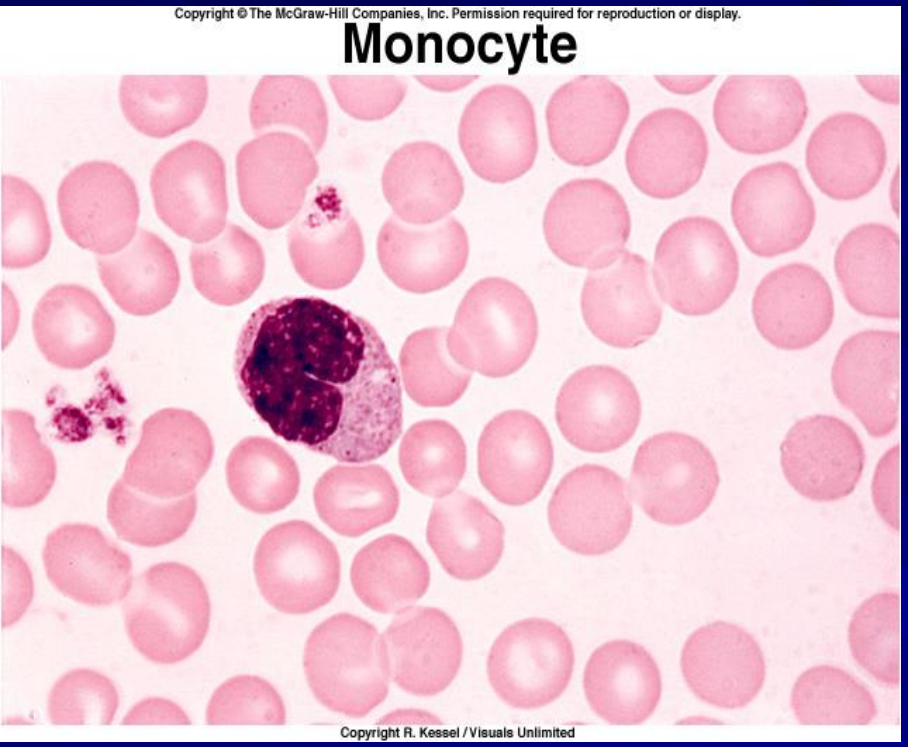


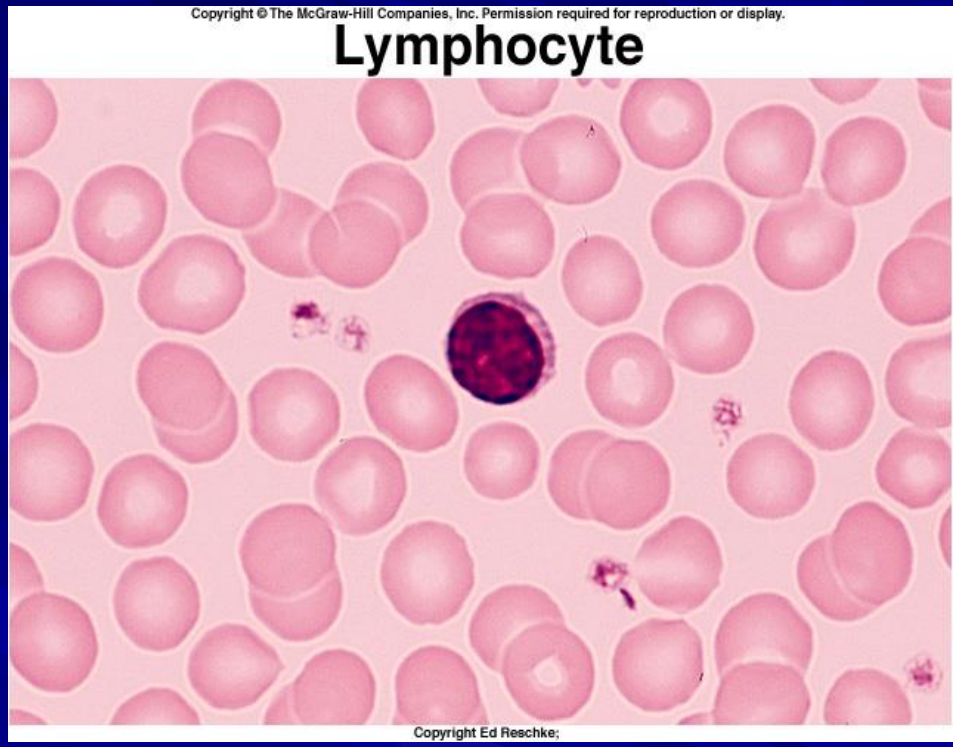
Basophils

- Granules stain deep blue in basic stain
- Nuclei have two lobes
- Migrate to damaged tissue
- Release **histamine** to promote inflammation and **heparin** to inhibit blood clotting
- Constitute less than 1% of leukocytes



Agranulocytes





Monocytes: largest cells; leave bloodstream and become macrophages; 3% to 9% of the leukocytes

Lymphocytes: T cells and B cells; important in immunity and antibody production; 35% to 33% of leukocytes