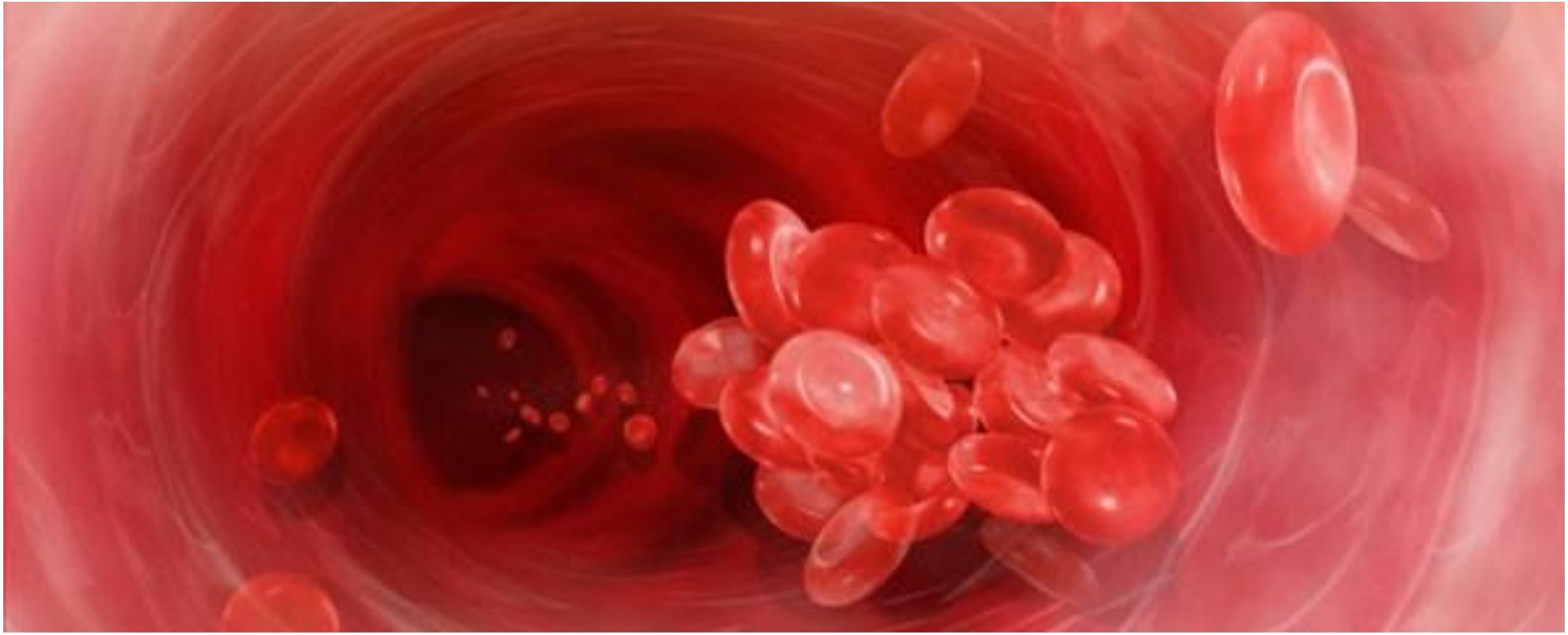
Cardiovascular System

Module 11



FUNCTIONS OF BLOOD

TRANSPORTATION

- Respiration
- Nutrient carrier from GIT
- Transportation of hormones from endocrine glands
- Transports metabolic wastes

REGULATION

- Regulates pH
- Adjusts and maintains body temperature
- Maintains water content of cells

PROTECTION

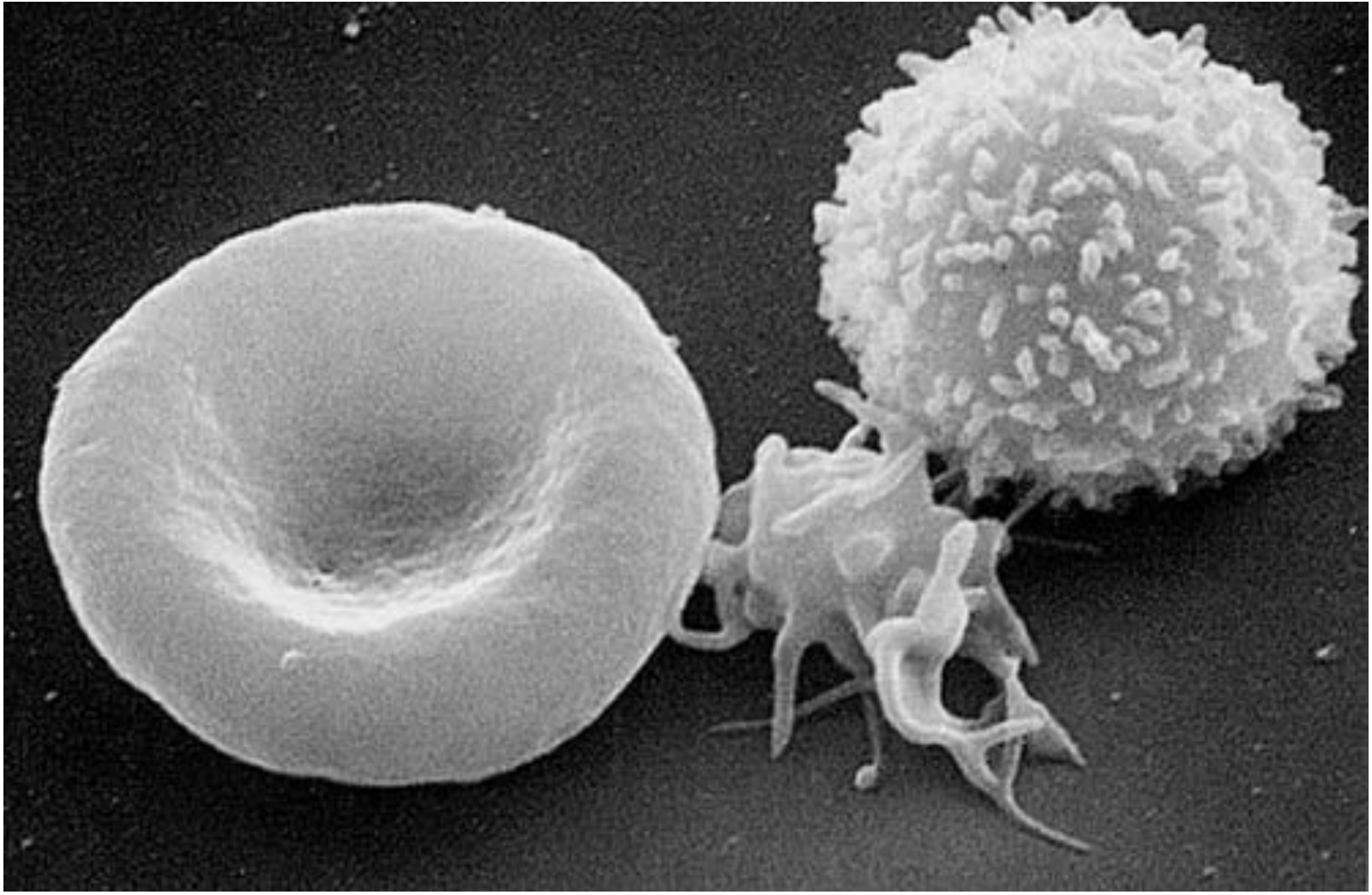
- WBC protects against disease by phagocytosis
- Reservoir for substances like water, electrolyte etc.
- Performs haemostasis

Physical Characteristics of Blood

- Average volume of blood:
  - 5–6 L for males; 4–5 L for females (Normovolemia)
  - Hypovolemia - low blood volume
  - Hypervolemia - high blood volume
- Viscosity (thickness) - 4 - 5 (where water = 1)
- The pH of blood is 7.35–7.45; x = 7.4
- Salinity = 0.85%
  - Reflects the concentration of NaCl in the blood
- Temperature is 38°C, slightly higher than "normal" body temperature
- Blood accounts for approximately 8% of body weight

Composition of Blood

1. Blood
   a. 55% Plasma
      i. 90% water
      ii. 7% proteins (albumin, globulins, fibrinogen)
      iii. 3% ions, nutrients, waste, gases, regulatory chemicals
   b. 45% Formed elements
      i. Erythrocytes (red blood cells) 95%
      ii. Leukocytes & platelets 5%



PLASMA - 55% of Total Blood Volume
91% Water
7% Blood Proteins (fibrinogen, albumin, globulin)
2% Nutrients (amino acids, sugars, lipids)
Hormones (erythropoietin, insulin, etc.)
Electrolytes (sodium, potassium, calcium, etc.)

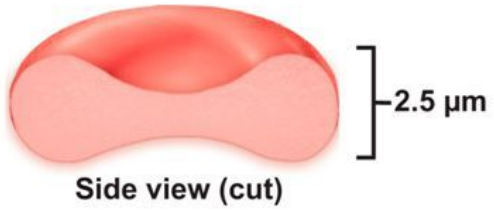
CELLULAR COMPONENTS - 45% of Total Blood Volume

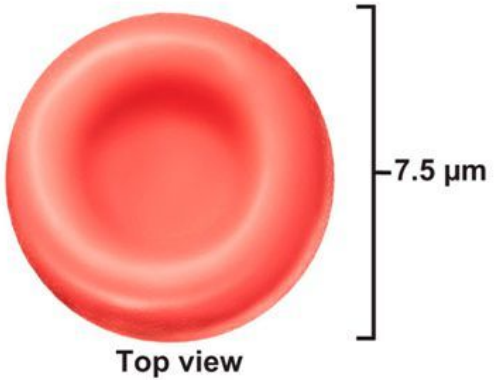
Buffy Coat
White Blood Cells (7000-9000 per mm^3 of blood
Platelets (250,000 per mm^3 of blood

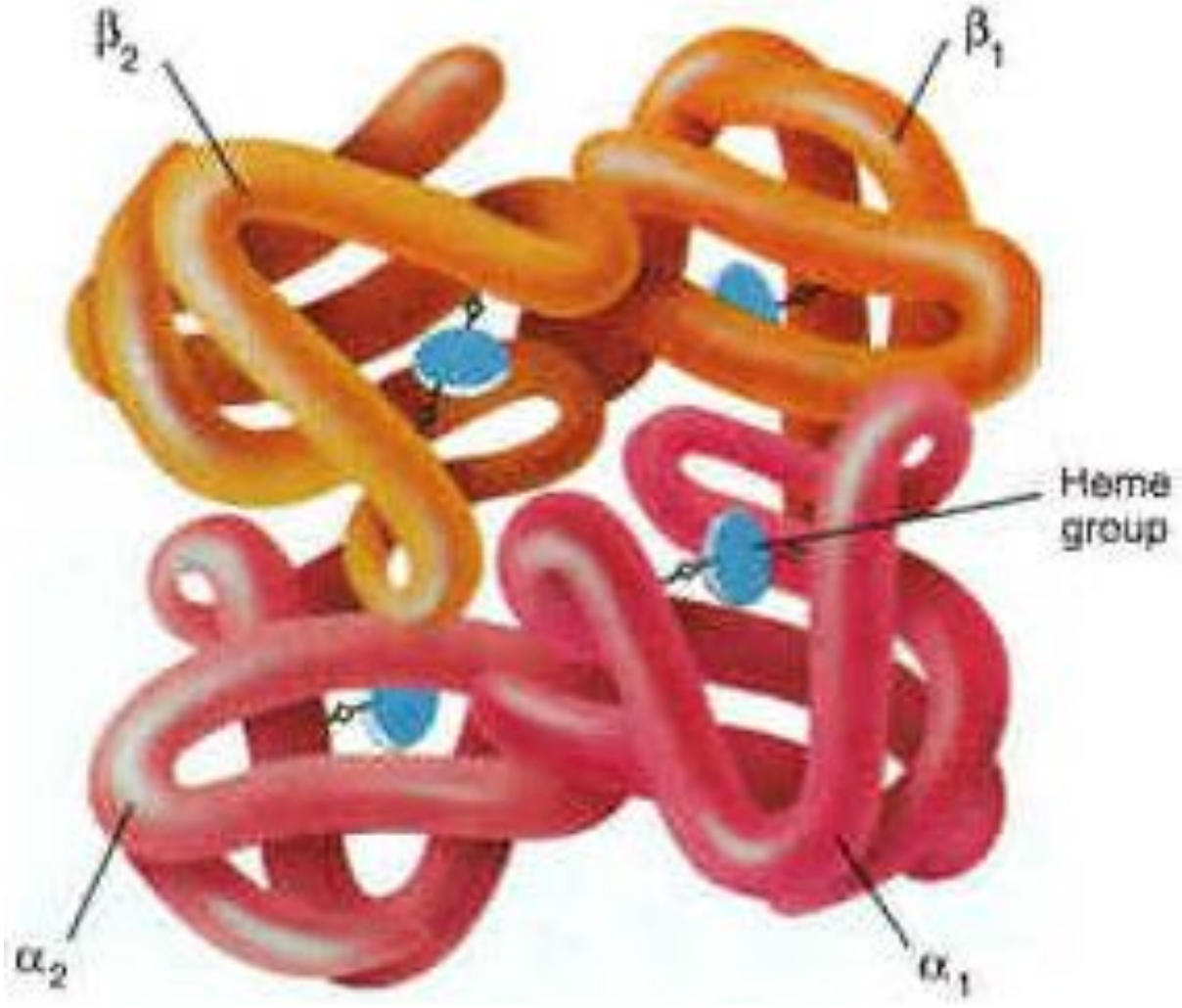
Red Blood Cells (RBCs)
About 5,000,000 per mm^3 of blood

Erythrocytes (Red Blood Cells)

- Main function is to carry oxygen
- Biconcave disks
- Essentially bags of hemoglobin; few organelles
- Anucleate (no nucleus)
- Outnumber white blood cells 1000:1
- Contain the plasma membrane protein spectrin and other proteins
- Major factor contributing to blood viscosity






β_2
β_1
Heme group
α_2
α_1

Transport of CO_2 in the blood

There are 3 ways in which carbon dioxide is transported in the blood:

DISSOLVED CO2

About 5 % of carbon dioxide is transported unchanged, simply dissolved in the plasma

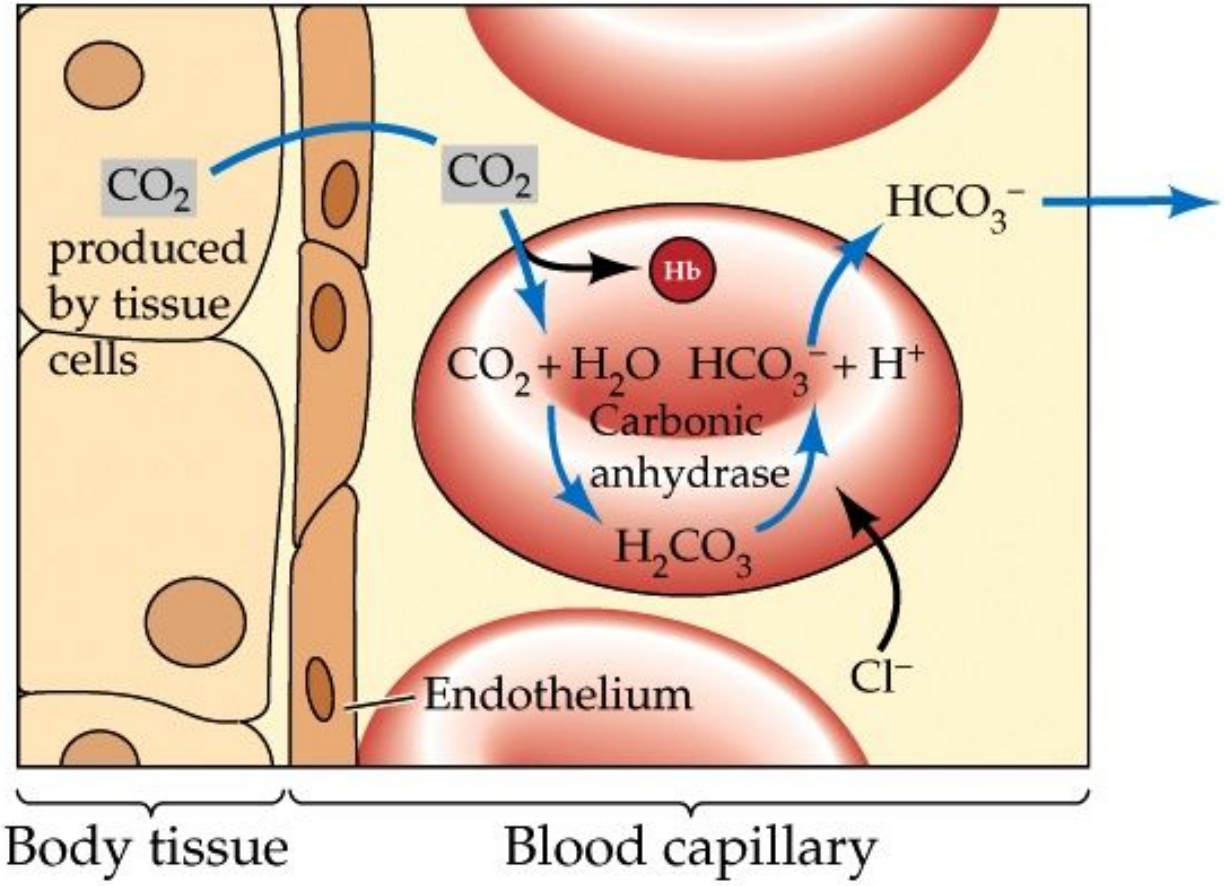
BOUND TO HAEMOGLOBIN

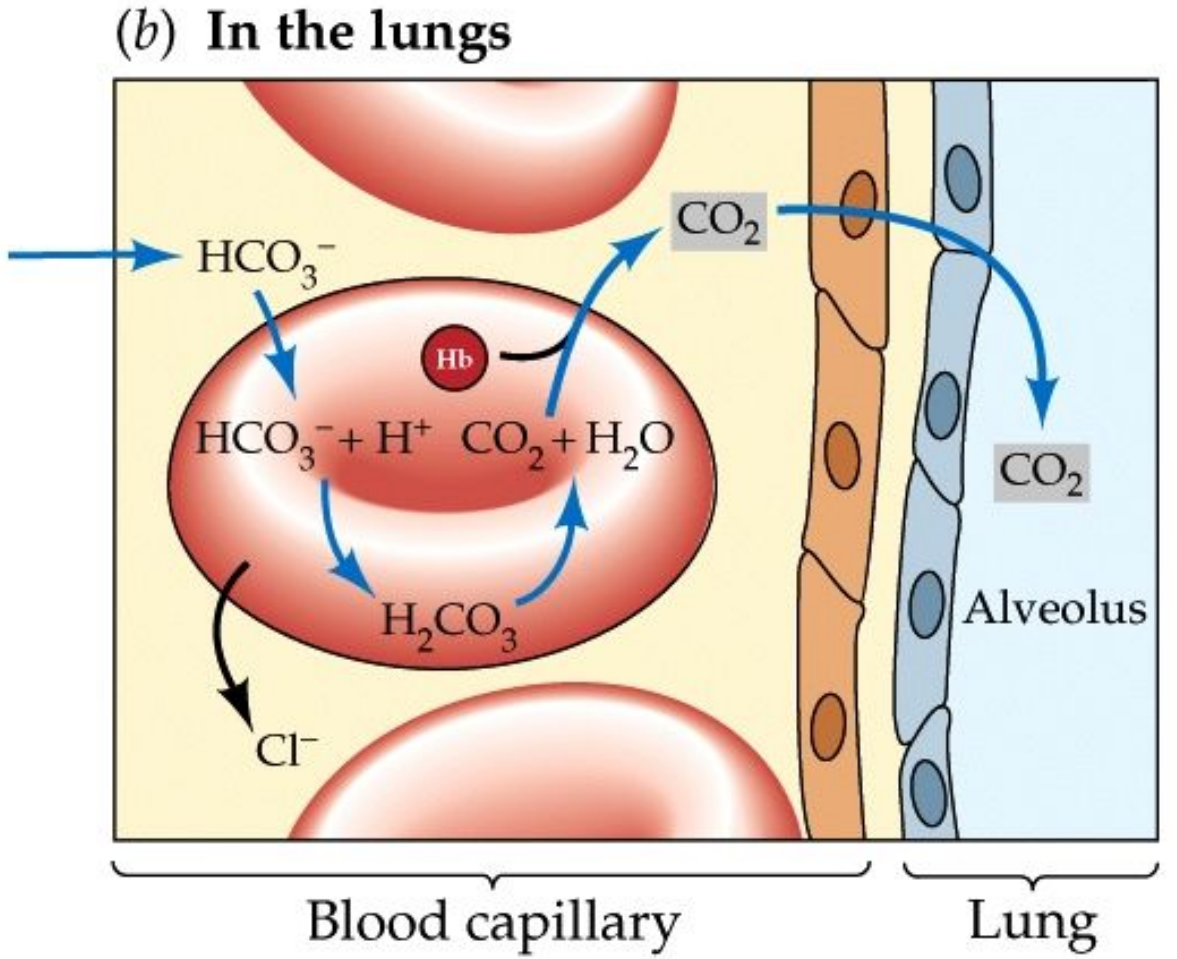
About 10 % of carbon dioxide is transported bound to haemoglobin. Carbon dioxide combines reversibly with haemoglobin to form carbamino-haemoglobin.

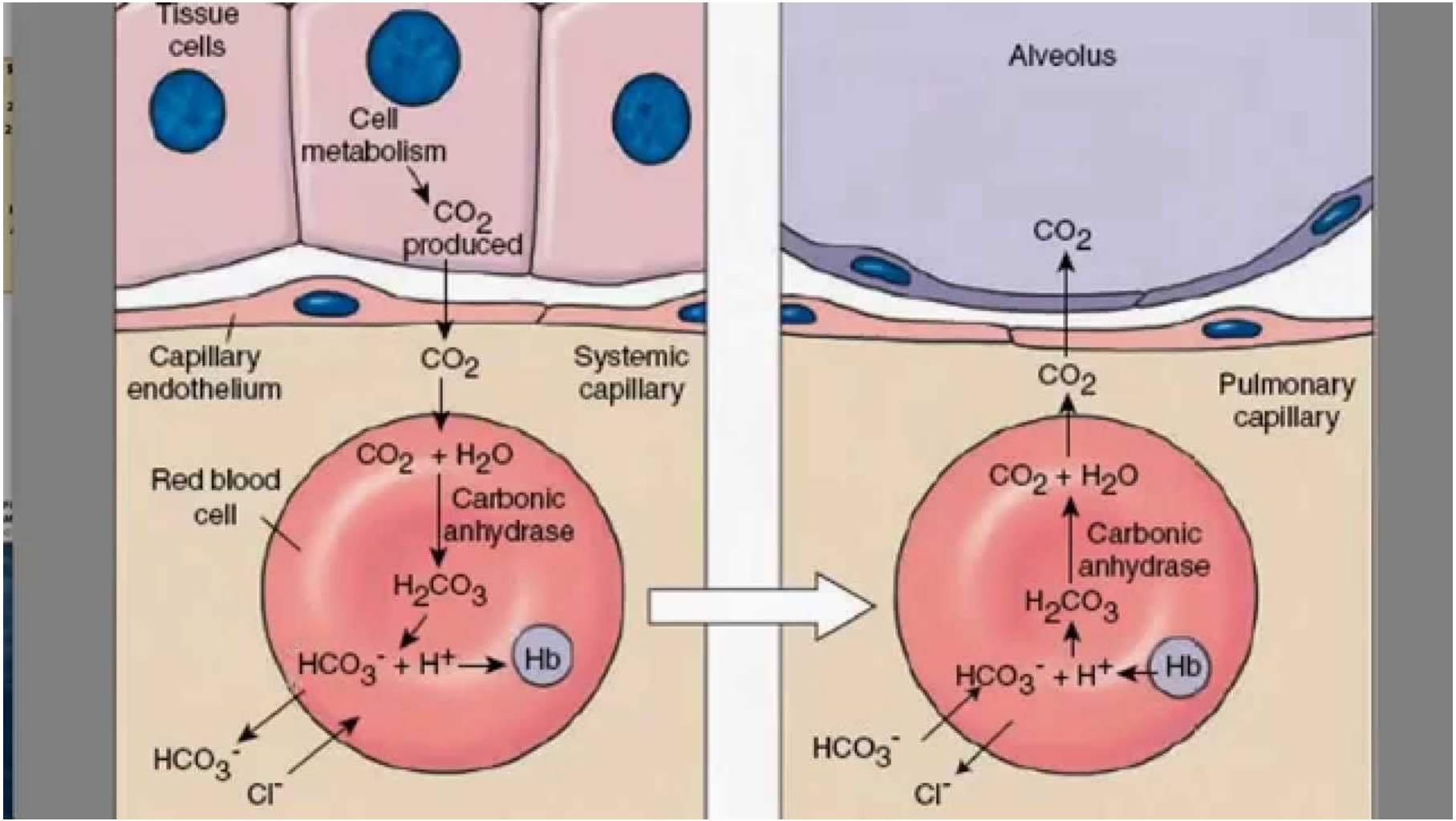
BICARBONATE IONS ($HCO3^-$)

85% of carbon dioxide is transported in this way

(*a*) **In body tissue**

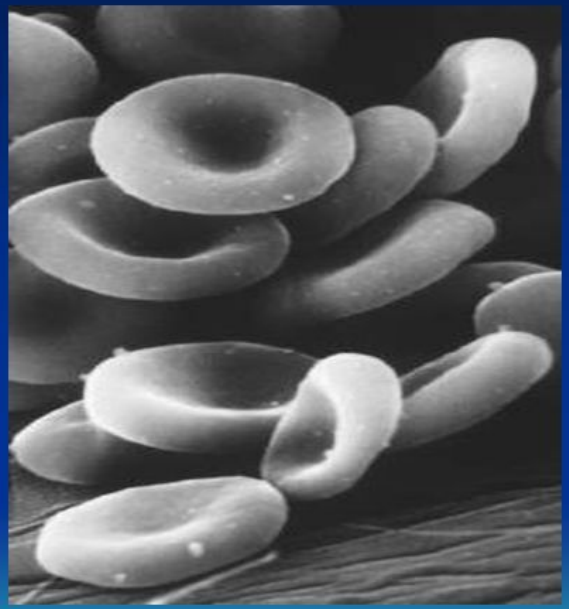





Tissue cells
Cell metabolism
CO_2 produced
Capillary endothelium
CO_2
Systemic capillary
Red blood cell
$CO_2 + H_2O$
Carbonic anhydrase
H_2CO_3
$HCO_3^- + H^+$
Hb
HCO_3^-
Cl^-
Alveolus
CO_2
CO_2
Pulmonary capillary
$CO_2 + H_2O$
Carbonic anhydrase
H_2CO_3
$HCO_3^- + H^+$
Hb
HCO_3^-
Cl^-

Causes of Anemia

- Lack of required nutrients
- Loss of blood
- Chronic Disease
- Genetic Abnormalities
- Inadequate production of red blood cells



White Blood Cells

1. Larger than Erythrocytes
2. Can move on their own (amoeboid movement)
3. Variety of types of White Blood Cells

White Blood Cells

Diapedesis - passage of white blood cells through pores in blood vessel to get into tissue spaces where the do their work.

How do they “know” the tissue “needs” them?

White Blood Cells

Chemotaxis - Attraction of cells to chemical stimuli

Leukocytes

white blood cells ~ WBC

agranular

lymphocytes
20 - 25 %

T-cell, B-cell, NK Cell

monocytes
3 - 8%

granular

basophils
.5 - 1%

neutrophils
60 - 70%

eosinophils
2 - 4%

Blood Smear Stain

Basophils, Eosinophils, Lymphocytes (T cells and B cells), Monocytes, Neutrophils

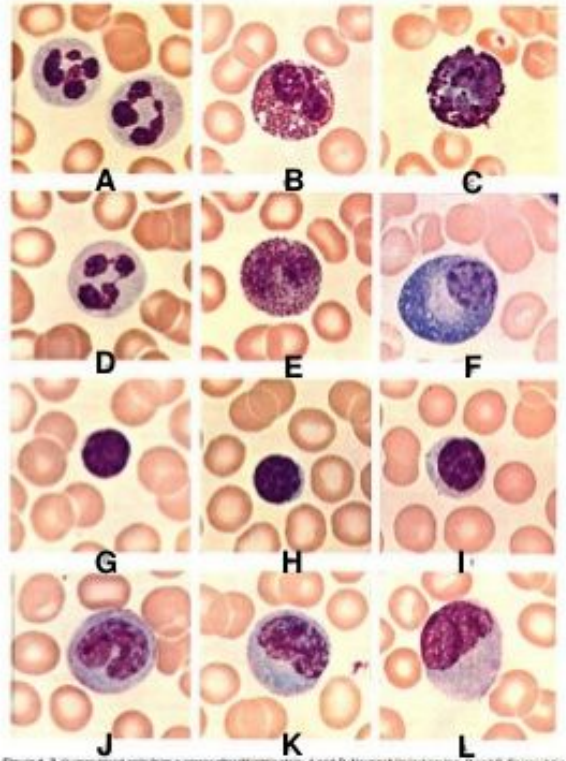


Figure 4–7. Human blood cells form a smear after Wright's stain. *A* and *D*, Neutrophilic leukocytes. *B* and *E*, Eosinophilic leukocytes. *C*, Basophilic leukocyte. *F*, Plasma cell; this is not a normal constituent of the peripheral blood but is included here for comparison with the nongranular leukocytes. *G* and *H*, Small lymphocytes. *I*, Medium lymphocytes. *J*, *K*, and *L*, Monocytes.

Source:

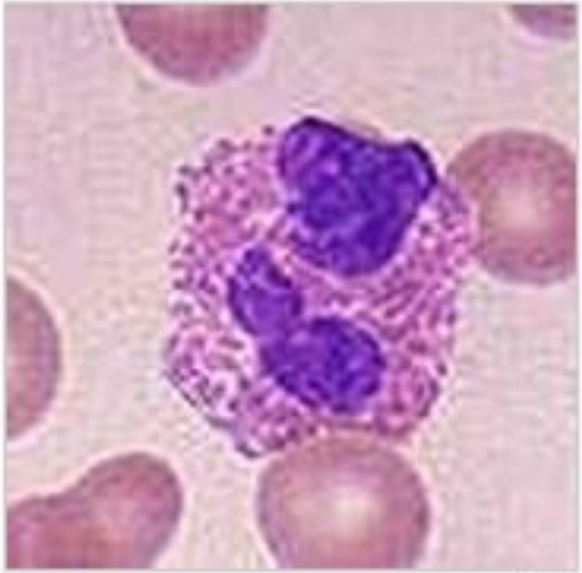
Smear from Wright's stain

A & D : Neutrophilic
B & E : Eosinophilic
C : basophilic
F : Plasma cell (not in blood)
G & H : small lymphocytes
I : medium lymphocytes
J, K & L : monocytes

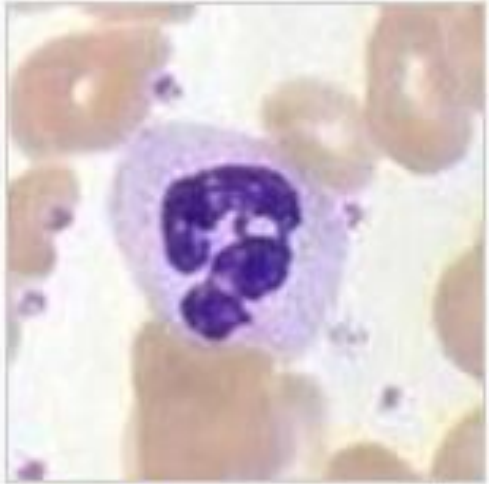
White Blood Cells - Granulocytes

1. Contain vesicles filled with substances that stain easily - giving a grainy look to them
2. Three types
   a. Neutrophil
   b. Basophil
   c. Eosionphil

basophil



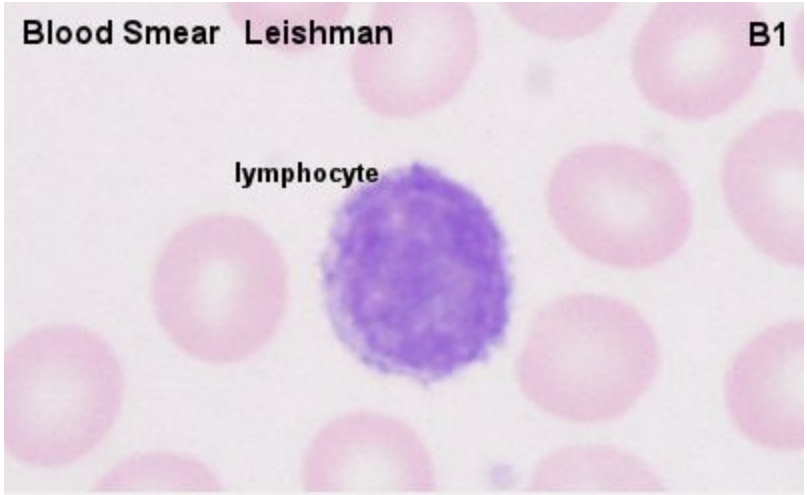
eosinophil

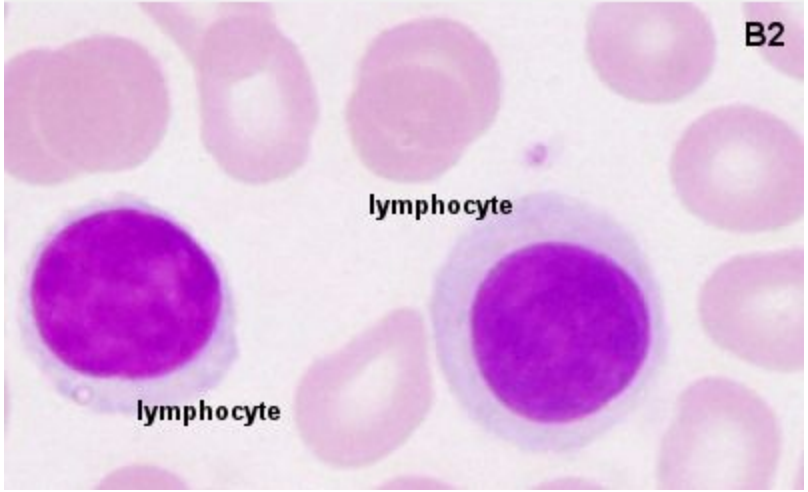


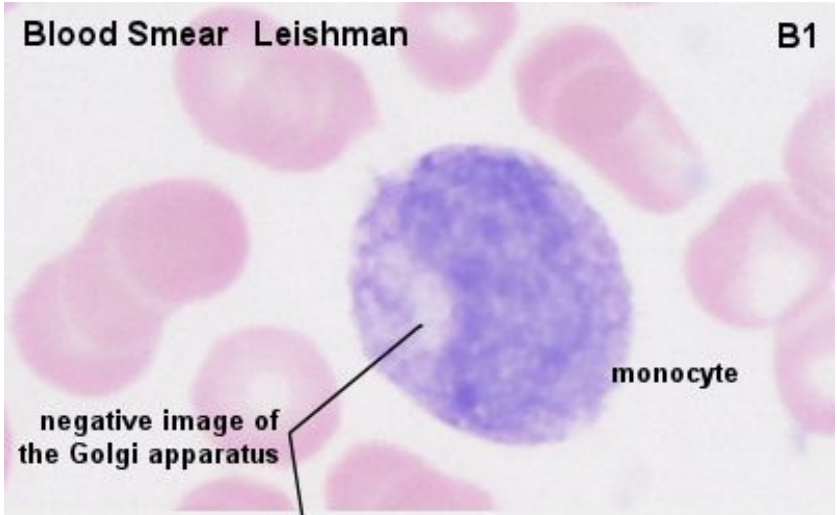
neutrophil

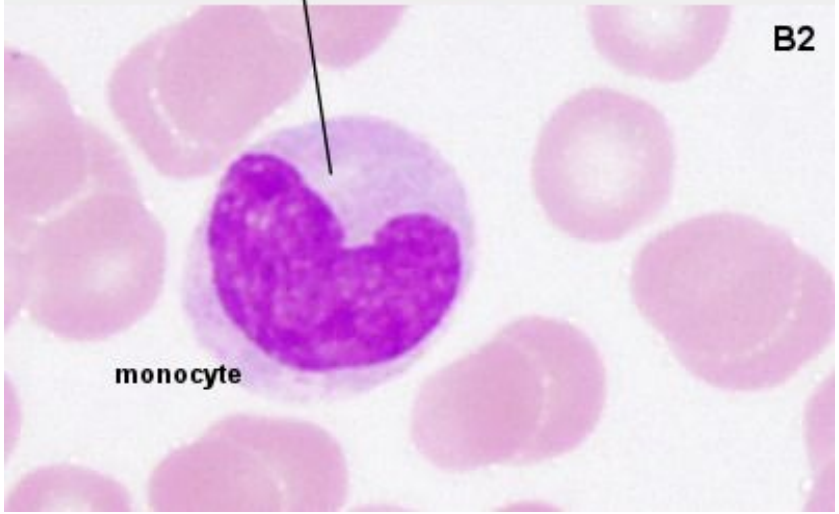
White Blood Cells - Agranulocytes

1. Vesicles are smaller and not seen with a light microscope therefore have a less grainy appearance
2. Two Types
    a. Lymphocyte
    b. Monocyte


Blood Smear Leishman
B1
lymphocyte


B2
lymphocyte
lymphocyte


Blood Smear Leishman
B1
monocyte
negative image of
the Golgi apparatus


B2
monocyte

Granulocytes

Neutrophils

1. Lobular nucleus
2. Less granules visible
3. First responders to infection via chemotaxis
4. Capable of phagocytosis

White Blood Cells

Phagocytosis - “cell eating” The process by which a cell engulfs and ingests a foreign or dead cell or dead parts

Pus - a mixture of dead or dying white blood cells, foreign cells such as bacteria, and fluid.

Granulocytes

Basophils

1. Rarest granulocytes
2. Attracted to blue dye
3. Bi-lobed nucleus
4. Many granules
5. Increase during allergic reactions

How are Basophils involved in allergic reactions?

Granulocytes

How are **Basophils** involved in allergic reactions?

1. Release histamine and heparin
   a. Histamines - promote inflammation which stimulates the immune system
   b. Heparin - prevents blood from clotting locally which allows the WBCs, antibodies and other immune factors to get to infection
   c. Eventually heparin is deactivated

Granulocytes

Eosinophils

1. Uncommon
2. Bi-lobed nucleus
3. Lots of red staining granules
4. Also increase during allergic reactions
5. Decrease inflammation
6. Also increase during parasitic infections

Agranulocytes

Lymphocytes

1. Smallest WBC; just a little larger than RBC
2. Second most common leukocyte
3. Dark staining nucleus, little cytoplasm
4. Produce antibodies and other immune protection

Agranulocytes

Monocytes

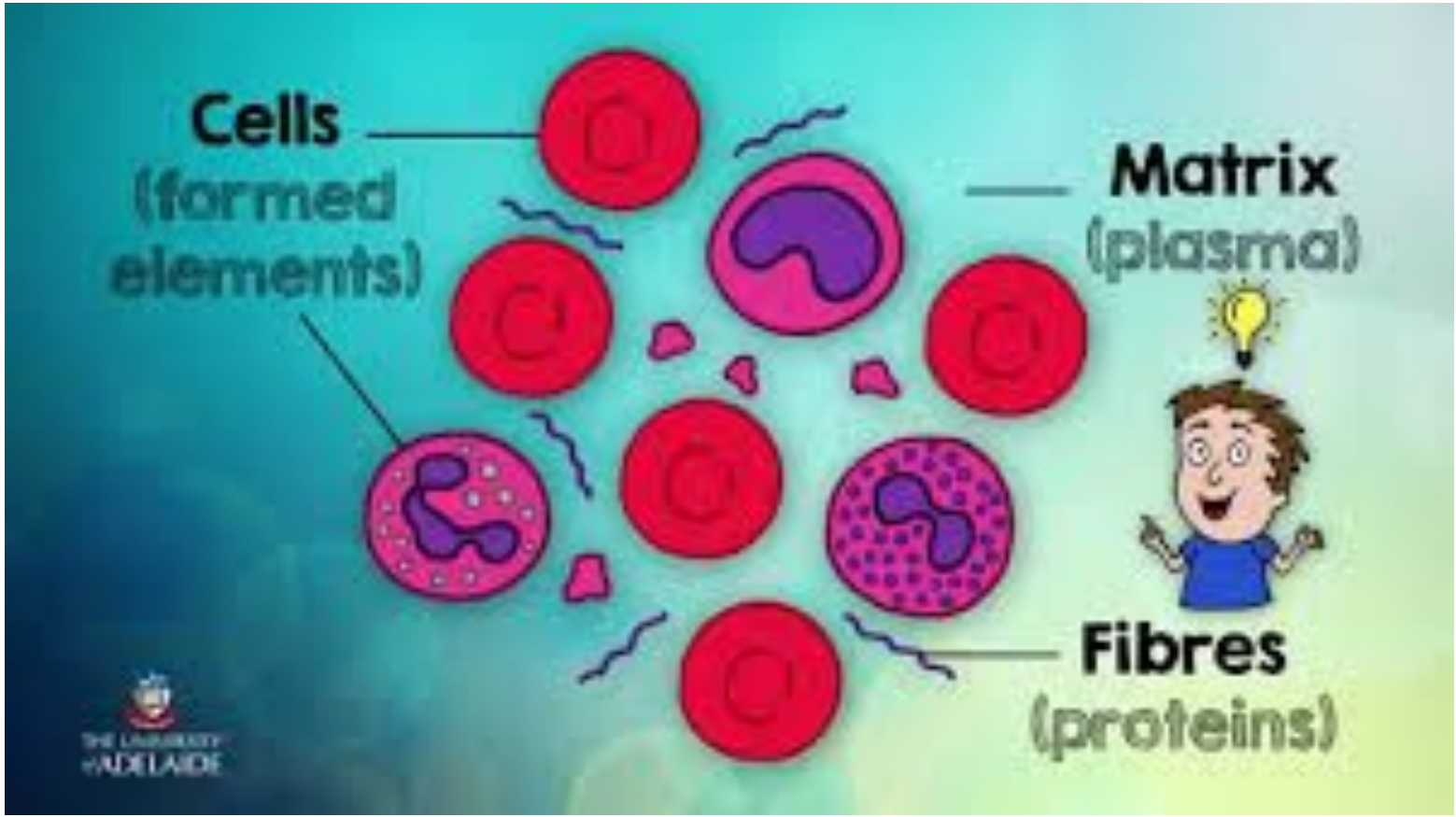
1. Largest WBC
2. Uncommon in numbers
3. Kidney shaped nucleus and more cytoplasm than lymphocyte
4. Very Phagocytic - Monster WBC!
5. Leave Blood via diapedesis and live in tissues and then are called macrophages

RED BLOOD CELLS:	Transport oxygen and carbon dioxide
WHITE BLOOD CELLS:	
NEUTROPHILS & MONOCYTES:	Phagocytic cells; engulf debris and pathogens
EOSINOPHILS:	Phagocytic cells; engulf items coated in antibodies
BASOPHILS:	Stimulate inflammation in tissues by releasing histamine
LYMPHOCYTES:	Immune defence against specific pathogens, toxins, or foreign proteins
PLATELETS:	Participate in clotting response

Hemopoiesis

The process by which the formed elements of blood are made in the red bone marrow.

What type of tissue is blood?



Hemostasis

The process by which the body stops blood loss.

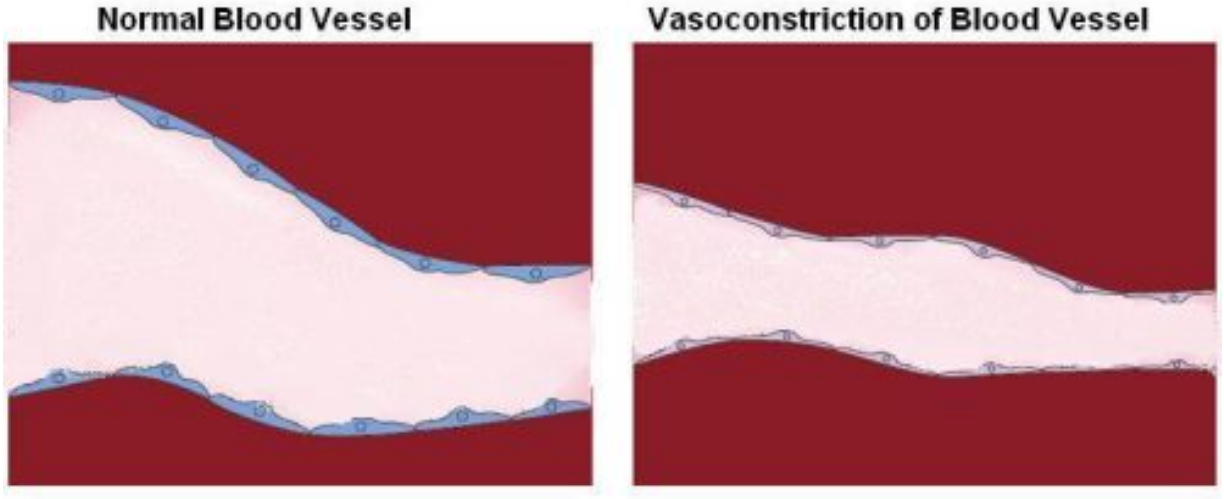
Hemostasis

Three Stages

1. Vasoconstriction
2. Platelet plug formation
3. Coagulation

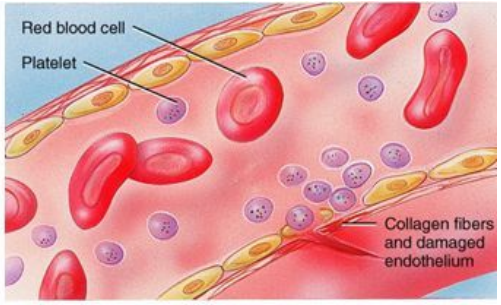
Hemostasis: Vasoconstriction Stage

Local reflex to narrow the blood vessel in order to prepare it for repair. The more damage, the greater the constriction.

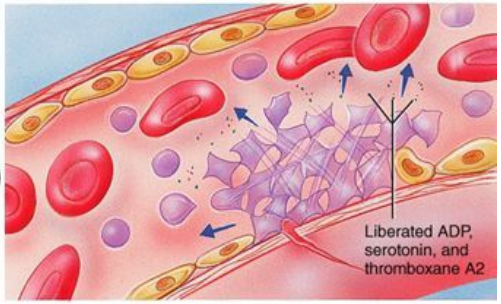


Hemostasis

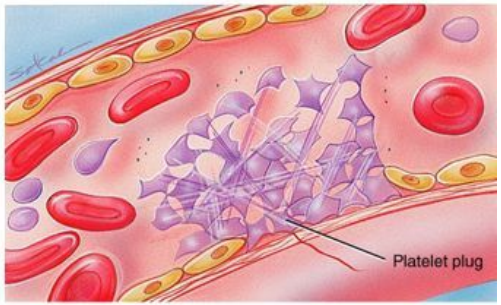
- Second - Platelet Plug Formation
  1) Platelet adhesion
     - platelets stick to exposed collagen
     - activates platelets
  2) Platelet release reaction
     - platelets attach to other platelets
     - release granule contents (thromboxane A_2)
     - promote vasoconstriction, platelet activation and aggregation
  3) Platelet aggregation ➲ platelet plug
     - blocks blood loss in small vessels
     - not as good in larger vessels



1 Platelet adhesion



2 Platelet release reaction



3 Platelet aggregation

An example of a positive feedback mechanism.

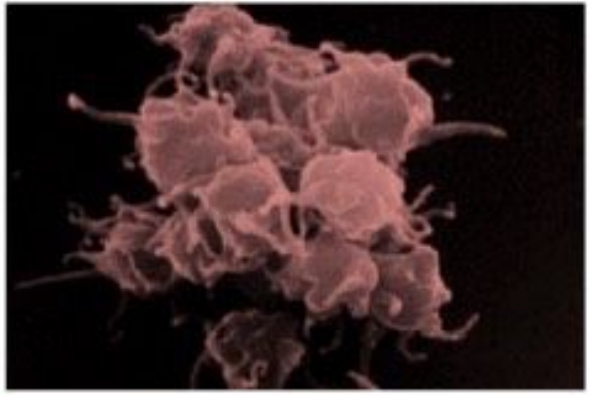
The release of **thromboxane** (a PG derivitive) is important in initiating several chemical processes.

Hemostasis: Platelet Plug (thrombus) Stage

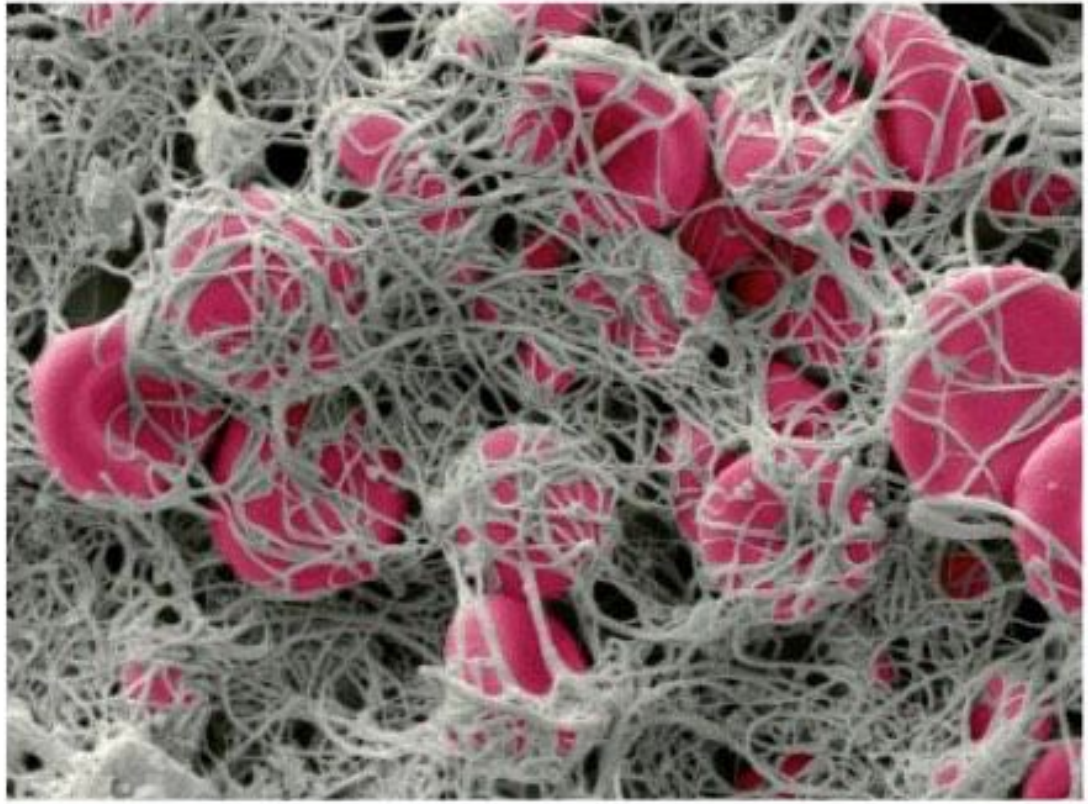
1. Good - prevents blood loss
2. Bad
   a. Coronary thrombosis - heart attack
   b. Embolus formed in legs and travels to heart, lungs, or brain

RESTING

ACTIVATED



Isolated Platelets



Fibrin Strands in a Blood Clot

Hemostasis: Coagulation Stage

A cascade of chemical reactions with the ultimate goal of converting **fibrinogen to fibrin** which is a long fiber that doesn’t dissolve in water.

Fibrin binds to platelets and traps RBCs forming a blood clot

Hemostasis: Coagulation Stage

What are coagulation factors?

They are proteins in blood plasma that initiate the blood coagulation process.

Most of these factors are formed in the liver

Extrinsic Pathway

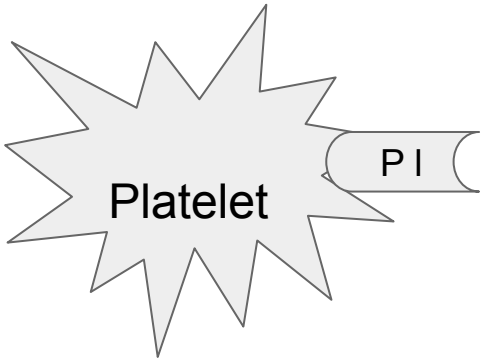
Tissue Damage releases **Tissue Factors (lipoproteins/phospholipid)**

Bind to Ca^{2+} and Factor VII to form

TF/Factor VII Complex

Activates Factor X

Activated Factor X + Factor V + Ca2+ + Phospholipids on platelet membrane



Leads to formation of Prothrombinase

Extrinsic Pathway

Prothrombinase catalyzes the reaction that converts prothrombin to thrombin

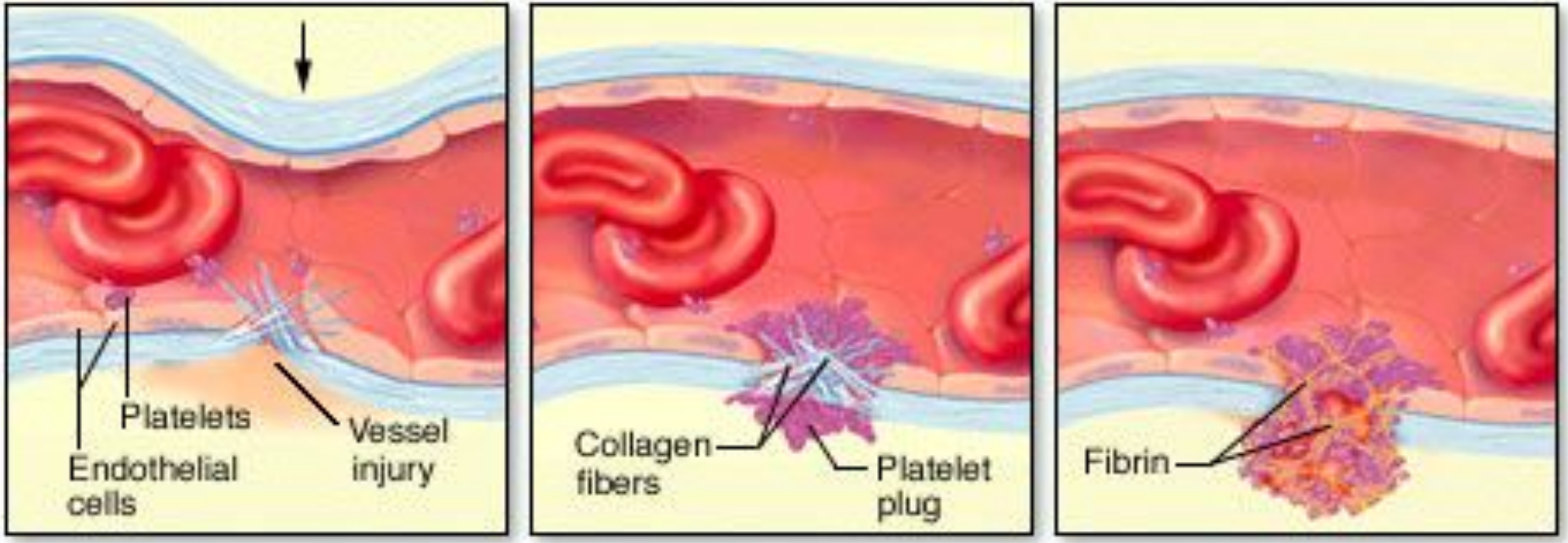
Prothrombinase

Prothrombin ⟹ **thrombin**

Thrombin:

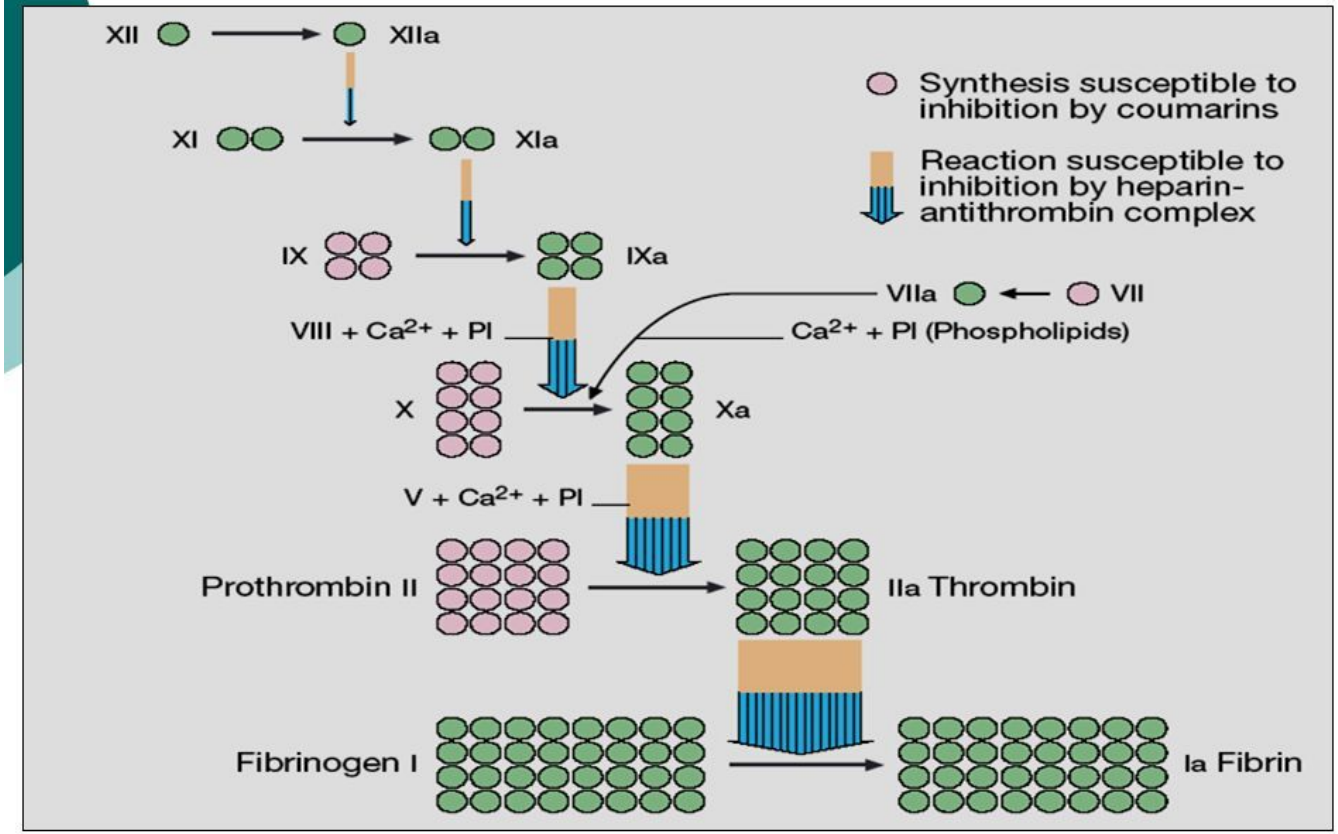
1. **Catalyzes the formation of fibrin from fibrinogen.**
2. **Reacts with FV to make more Prothrombinase (increase thrombin and fibrin.**
3. **Reacts with FVIII to make more FXa (increase thrombin/fibrin)**
4. **Reacts with FXIII to activate FVIII to stabilize the clot.**

Fibrin: **1. Makes long strands to form blood clot.**



(a) Vasoconstriction (b) Platelet aggregation (c) Clot formation

COAGULATION CASCADE




HEMOPHILIA
MEDIC

Injury Occurs

1. Injury to blood vessel results in bleeding.

2. Vessel constricts and clotting factors are activated.

Normal

3. Along with other substances, clotting factor VIII causes a strong platelet plug to form.

4. A stable fibrin clot forms over the platelet plug as a final seal on the injury, and the bleeding stops.

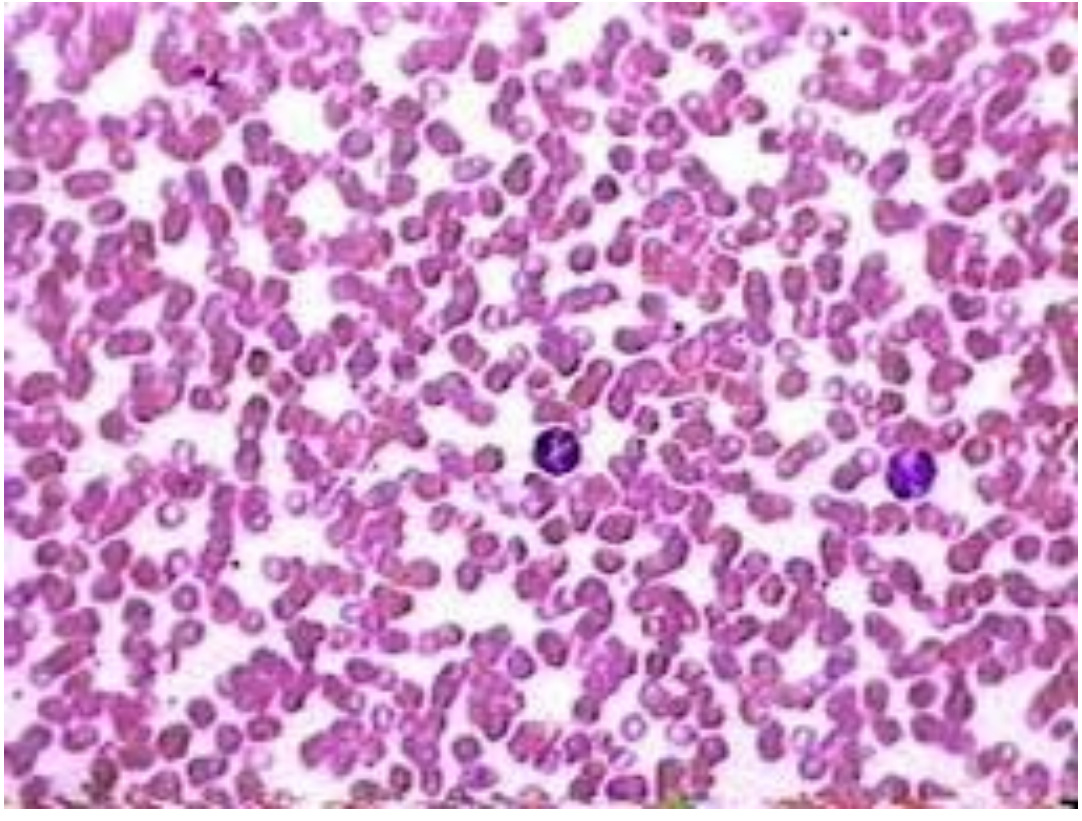
Hemophilia A

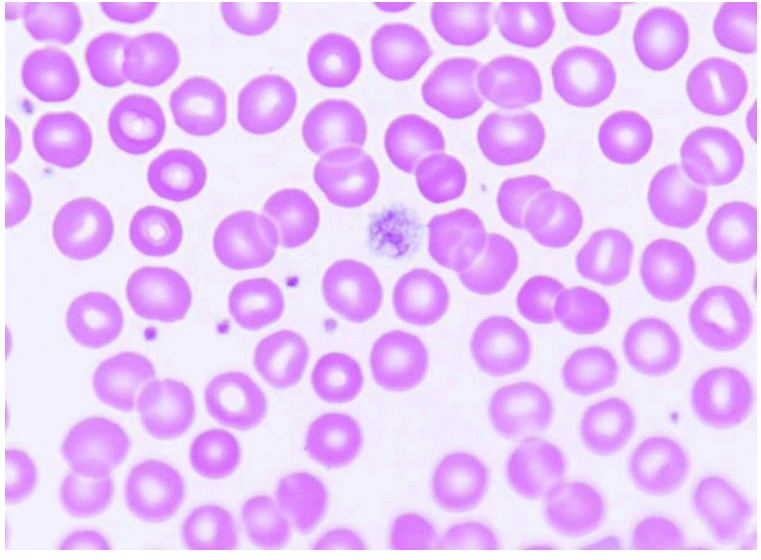
3. Lack of clotting factor VIII causes a weak platelet plug to form.

4. Incomplete and/or delayed fibrin clot allows bleeding to continue.

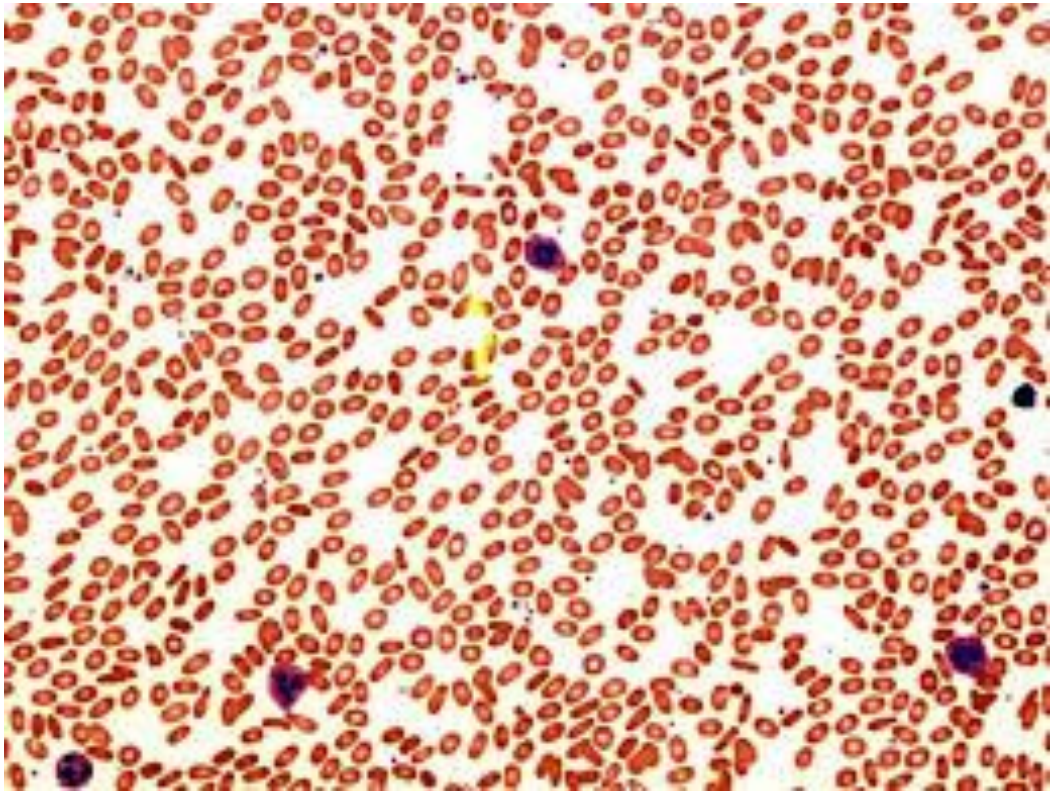
Medical Slides

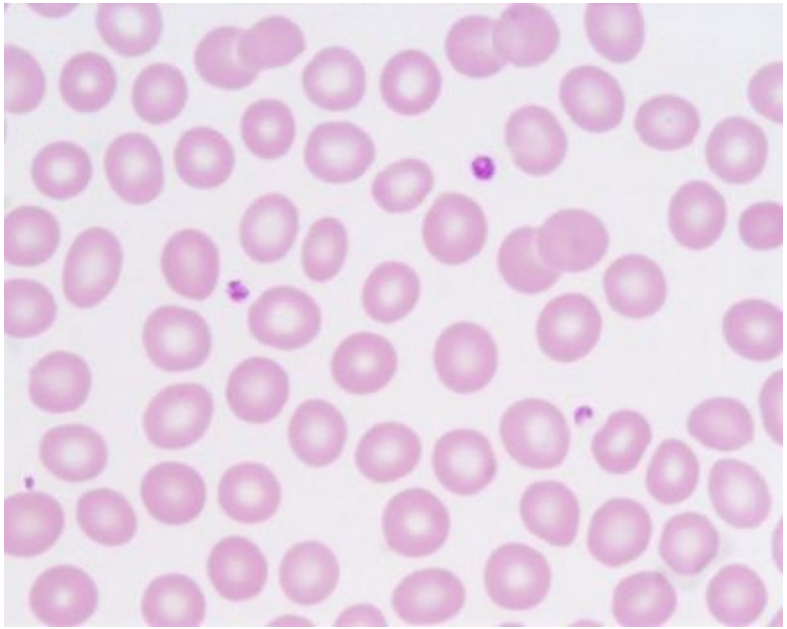
Patient 1



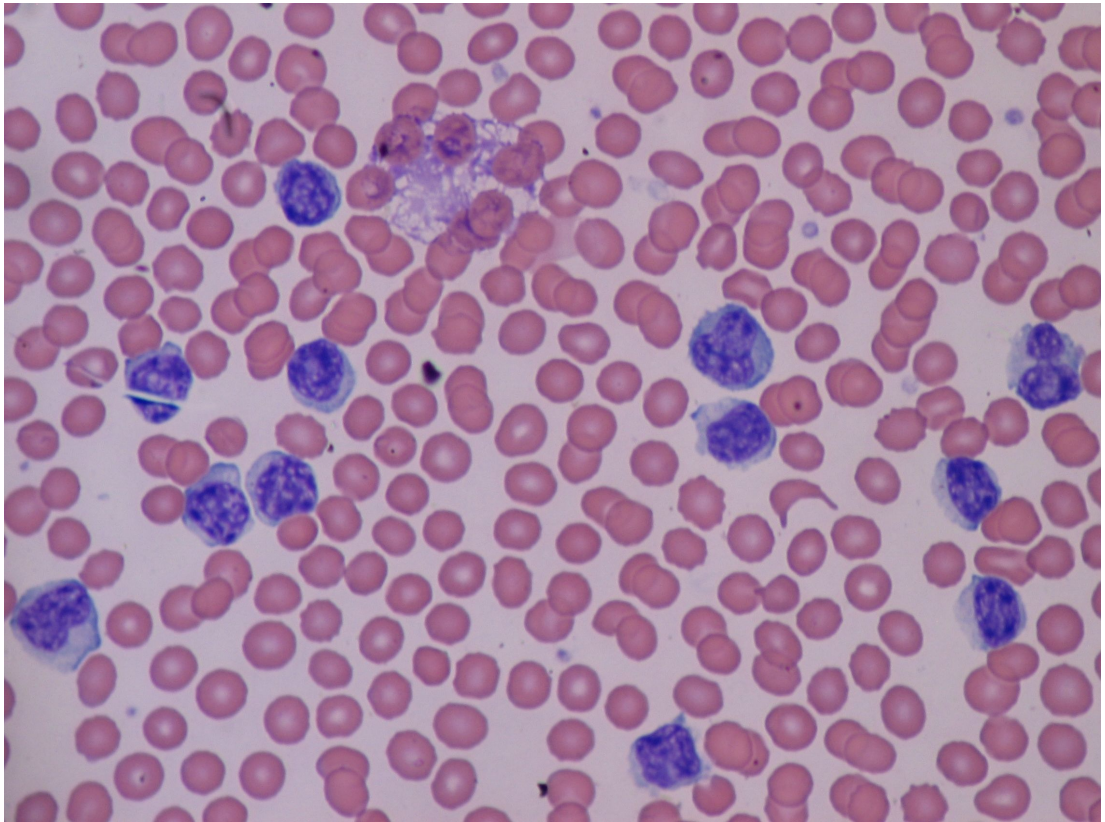


Patient 2

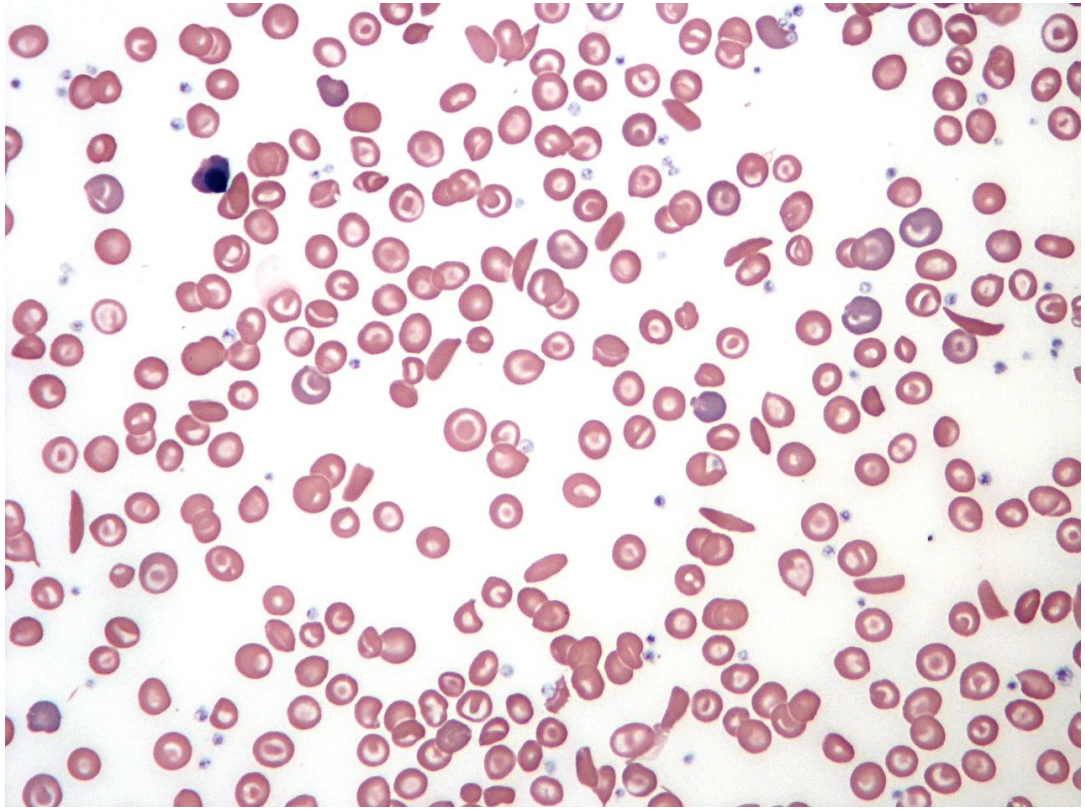


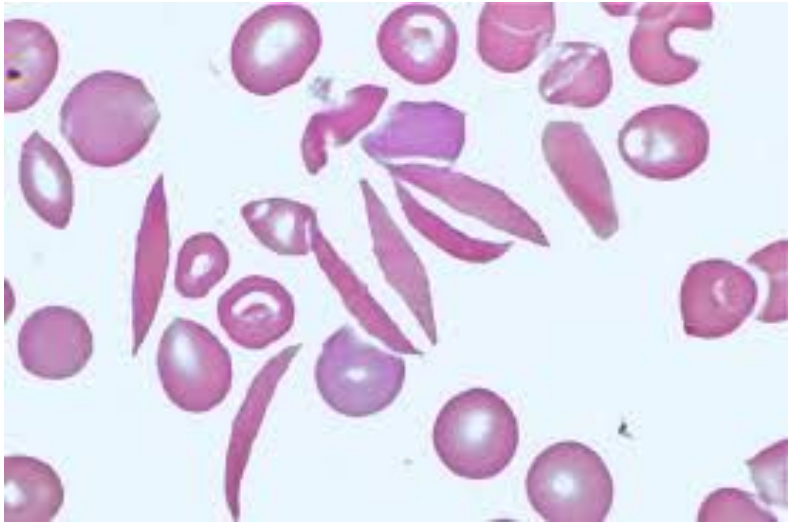


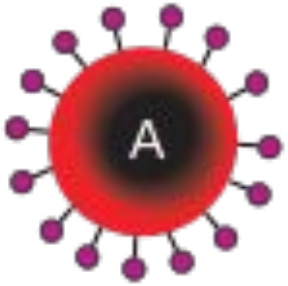
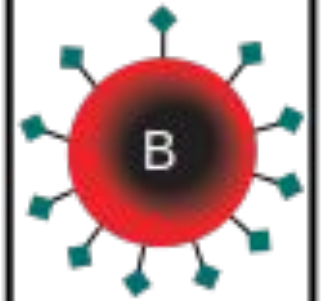
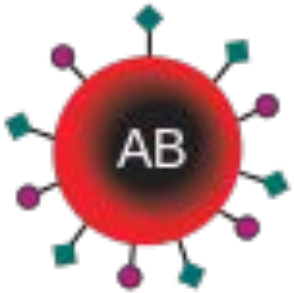
Patient 3



Patient 4





	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in Plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in Red Blood Cell	 A antigen	 B antigen	 A and B antigens	None

Rh Factor

An antigen that is found on erythrocytes and indicated as positive if present and negative if not.

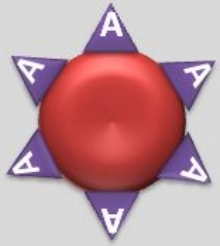
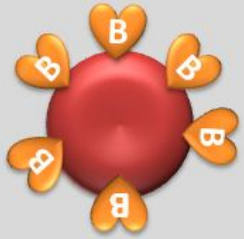
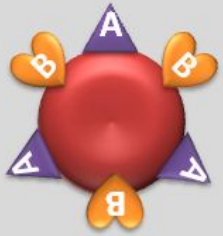
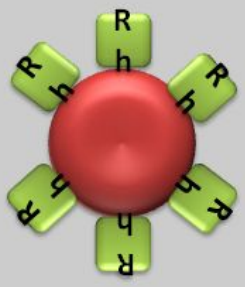
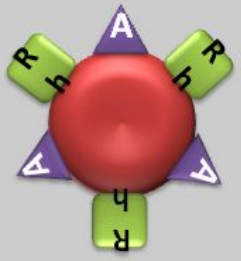
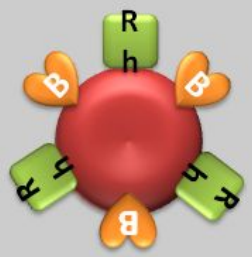
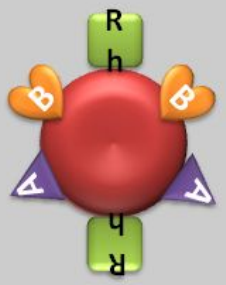
Dominant gene. Unlike other blood types, the antibody against the Rh factor isn't formed unless exposed to the antigen.

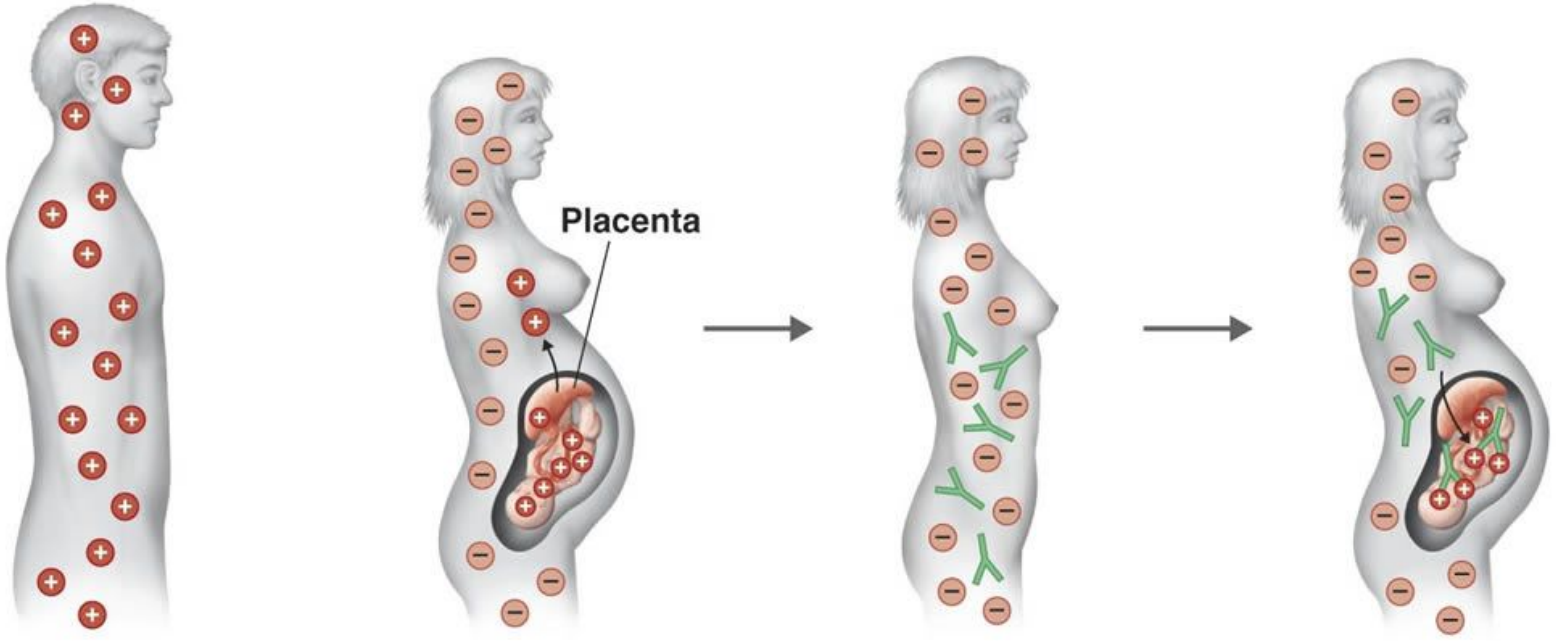
This can result in hemolytic disease of an unborn baby.

Rh Blood Group System

present (+)
Rh positive

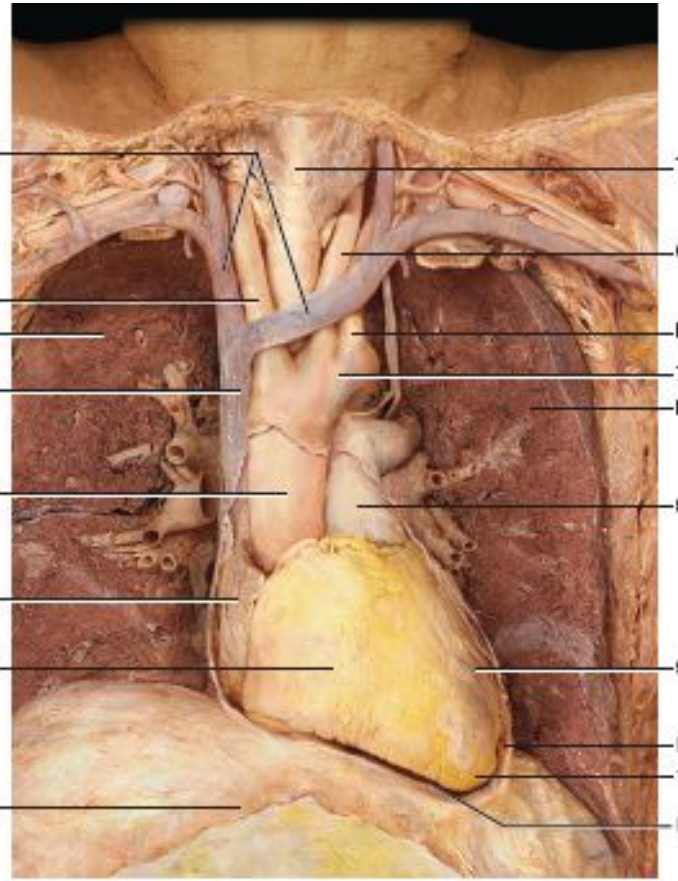
absent (-)
Rh negative

O-	A-	B-	AB-
			
O+	A+	B+	AB+
			



1. Rh^+ father.
2. Rh^- mother carrying her first Rh^+ fetus. Rh antigens from the developing fetus can enter the mother's blood during delivery.
3. In response to the fetal Rh antigens, the mother will produce anti-Rh antibodies.
4. If the woman becomes pregnant with another Rh^+ fetus, her anti-Rh antibodies will cross the placenta and damage fetal red blood cells.

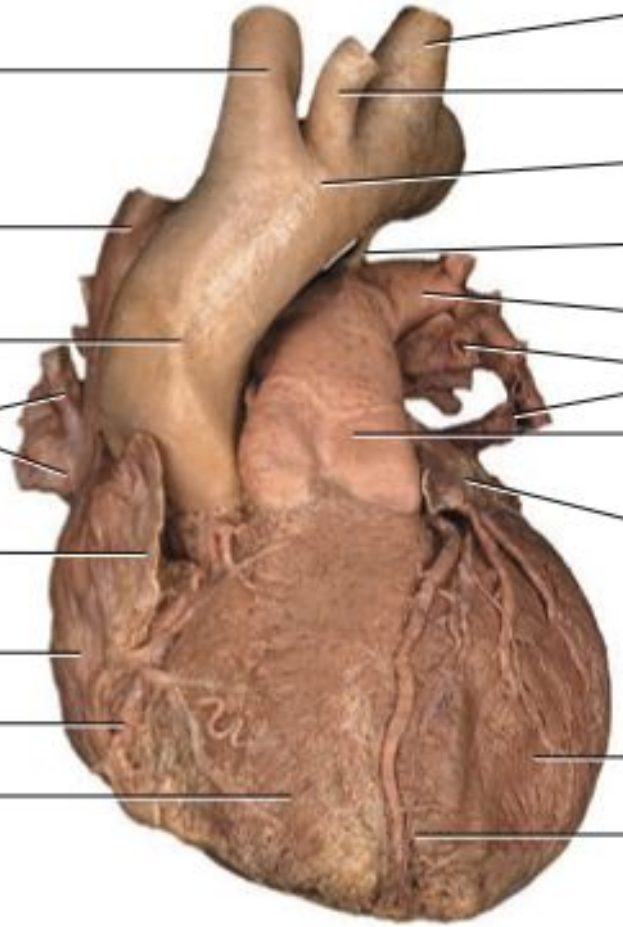
Heart



Terms:

Aortic arch
Apex of heart
Ascending aorta
Brachiocephalic trunk
Left common carotid artery
Left ventricle
Pulmonary trunk
Right atrium
Right ventricle
Superior vena cava

0.3 CONTINUED



Brachiocephalic trunk

Superior vena cava

Ascending aorta

Right pulmonary veins

RIGHT AURICLE OF RIGHT ATRIUM

RIGHT ATRIUM

CORONARY SULCUS

RIGHT VENTRICLE

Left subclavian artery

Left common carotid artery

Arch of aorta

Ligamentum arteriosum

Left pulmonary artery

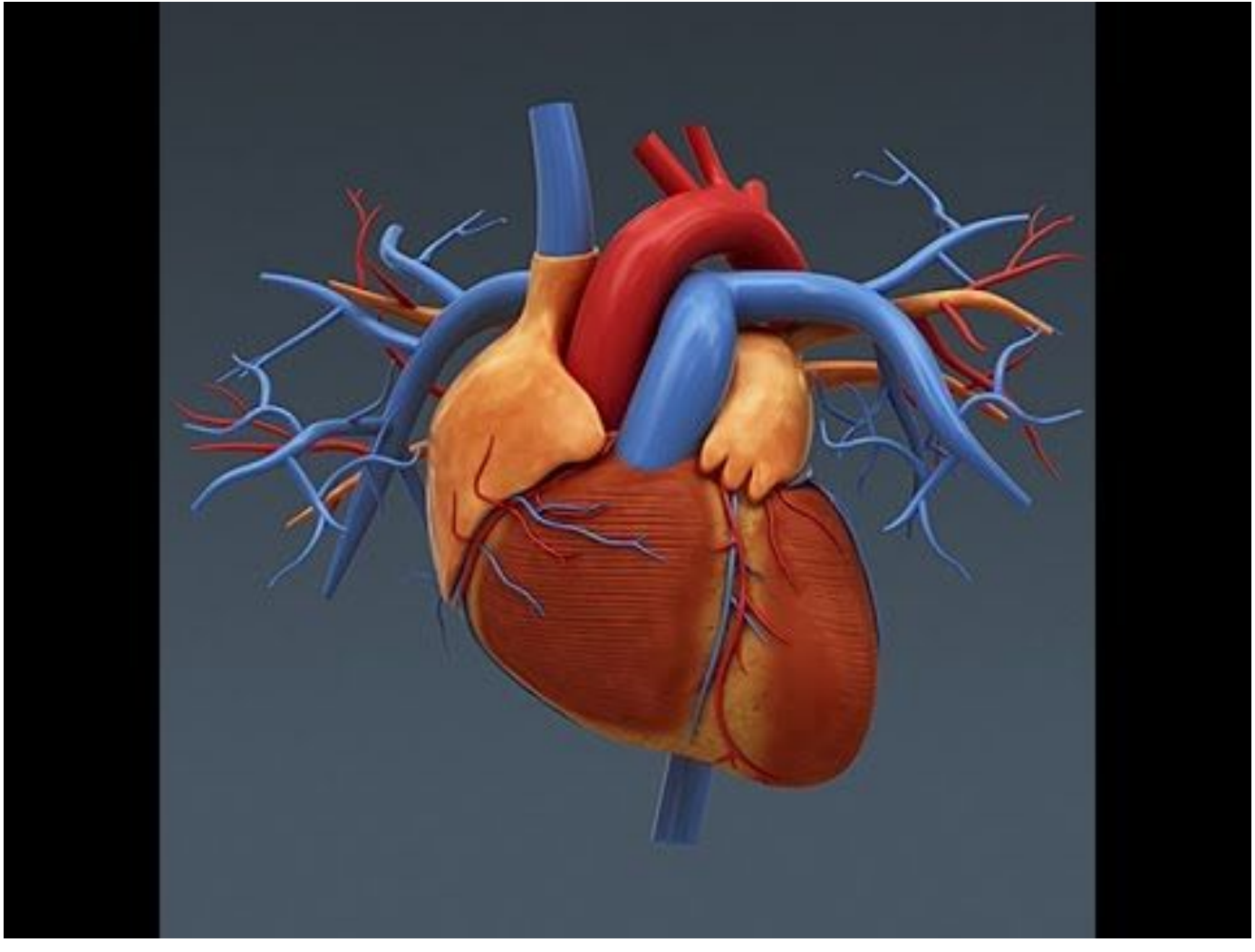
Left pulmonary veins

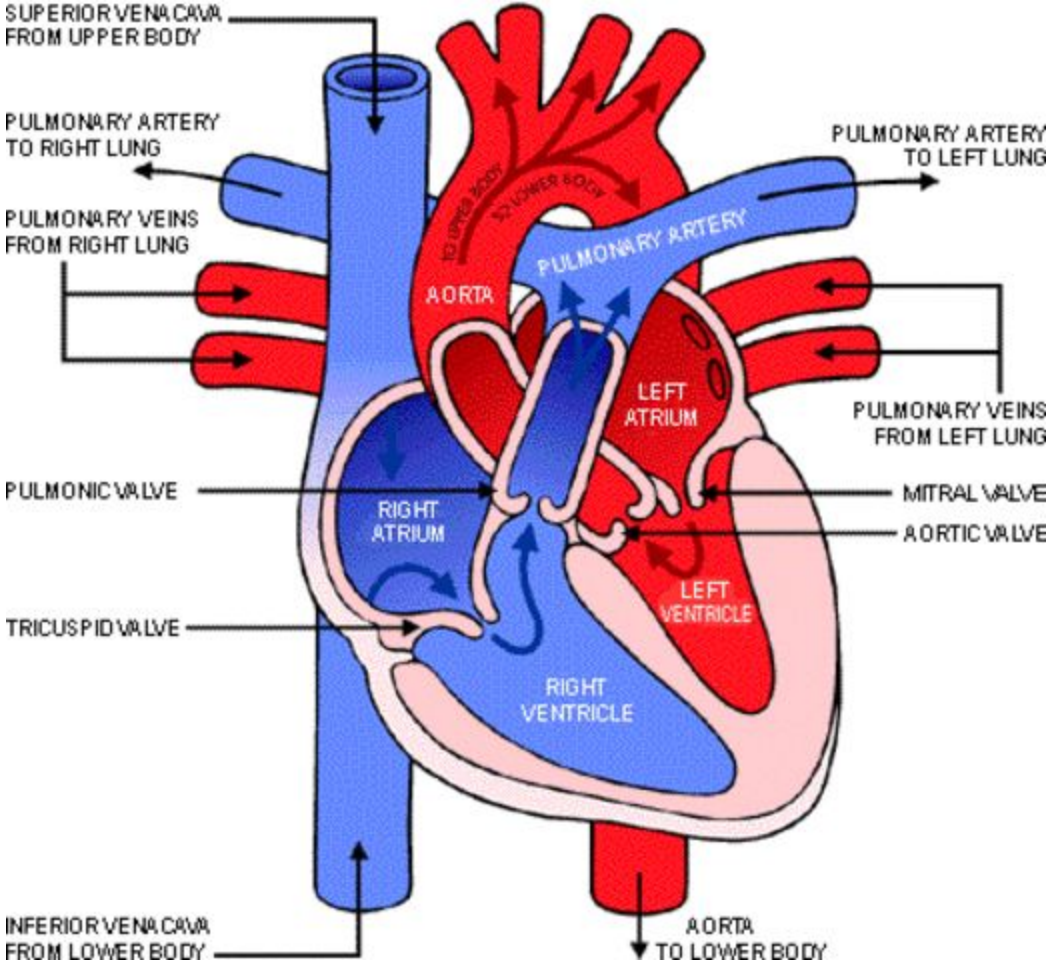
Pulmonary trunk

LEFT AURICLE OF LEFT ATRIUM

LEFT VENTRICLE

ANTERIOR INTERVENTRICULAR SULCUS




SUPERIOR VENA CAVA
FROM UPPER BODY
PULMONARY ARTERY
TO RIGHT LUNG
PULMONARY VEINS
FROM RIGHT LUNG
PULMONARY ARTERY
TO LEFT LUNG
PULMONARY VEINS
FROM LEFT LUNG
TO UPPER BODY
TO LOWER BODY
AORTA
PULMONARY ARTERY
LEFT
ATRIUM
PULMONIC VALVE
RIGHT
ATRIUM
MITRAL VALVE
AORTIC VALVE
LEFT
VENTRICLE
TRICUSPID VALVE
RIGHT
VENTRICLE
INFERIOR VENA CAVA
FROM LOWER BODY
AORTA
TO LOWER BODY