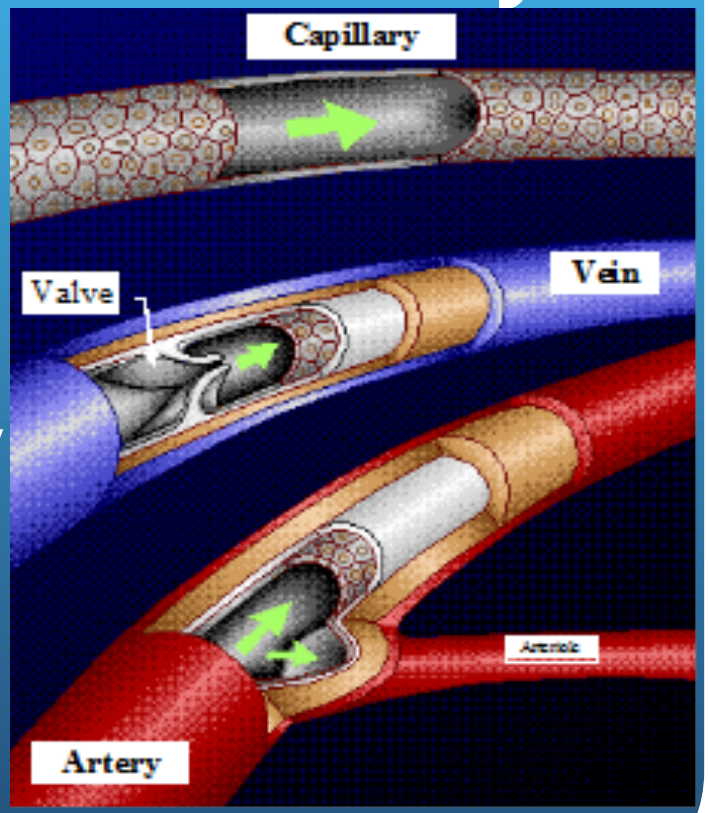
The Circulatory System!

A. Functions of the Circulatory system:

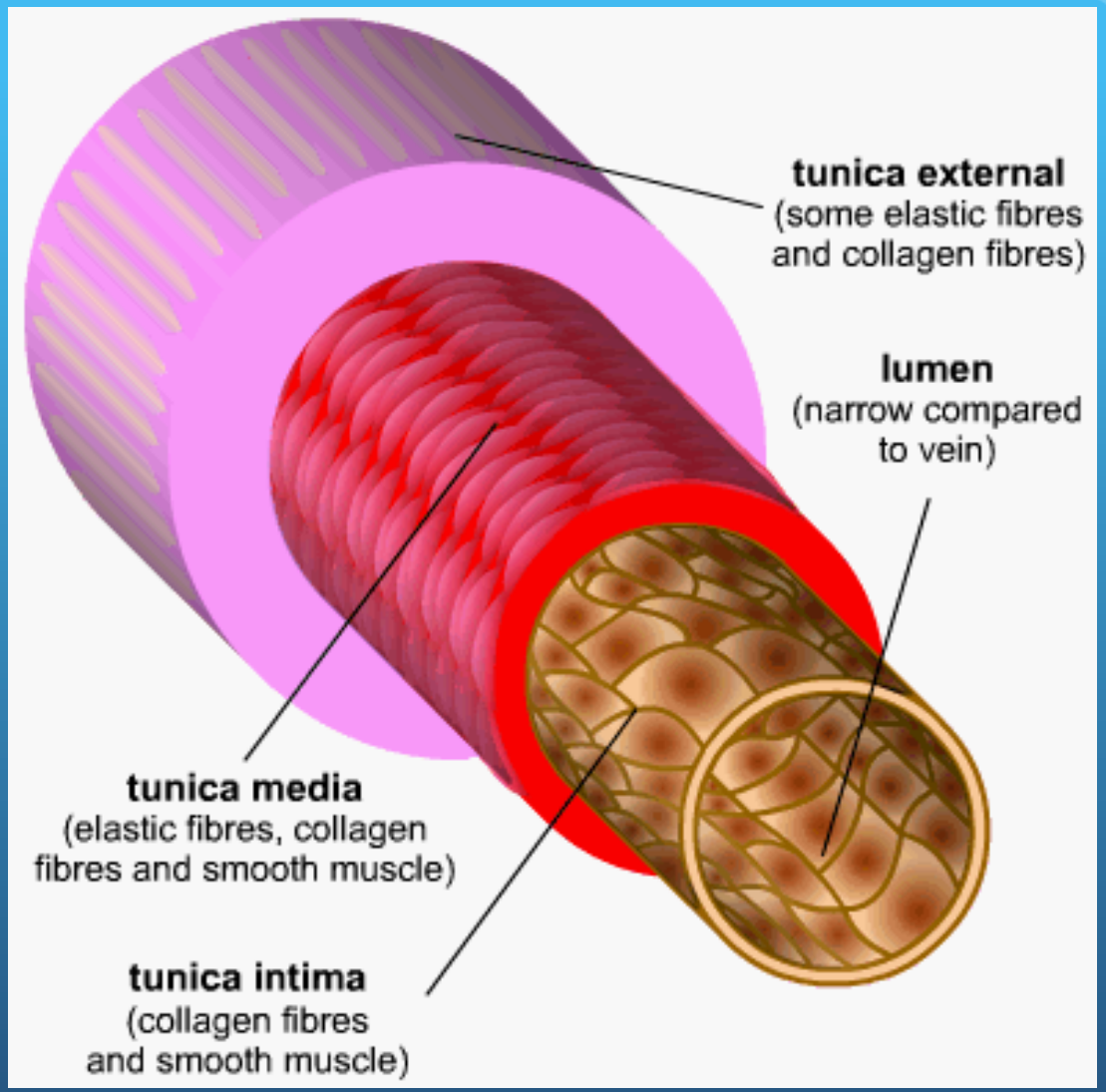
1. Bring nutrients to the cells.
2. Take wastes away from the cells.



Five Types of Blood Vessels

I. Arteries and arterioles
   A. Carry blood away from the heart to the tissues.
   B. Arteries
      1. Large, carry blood away from the heart.
      2. Thick elastic walls to allow for it to stretch.
      3. Surrounded by smooth muscle to control the diameter of the artery.

Artery Structure



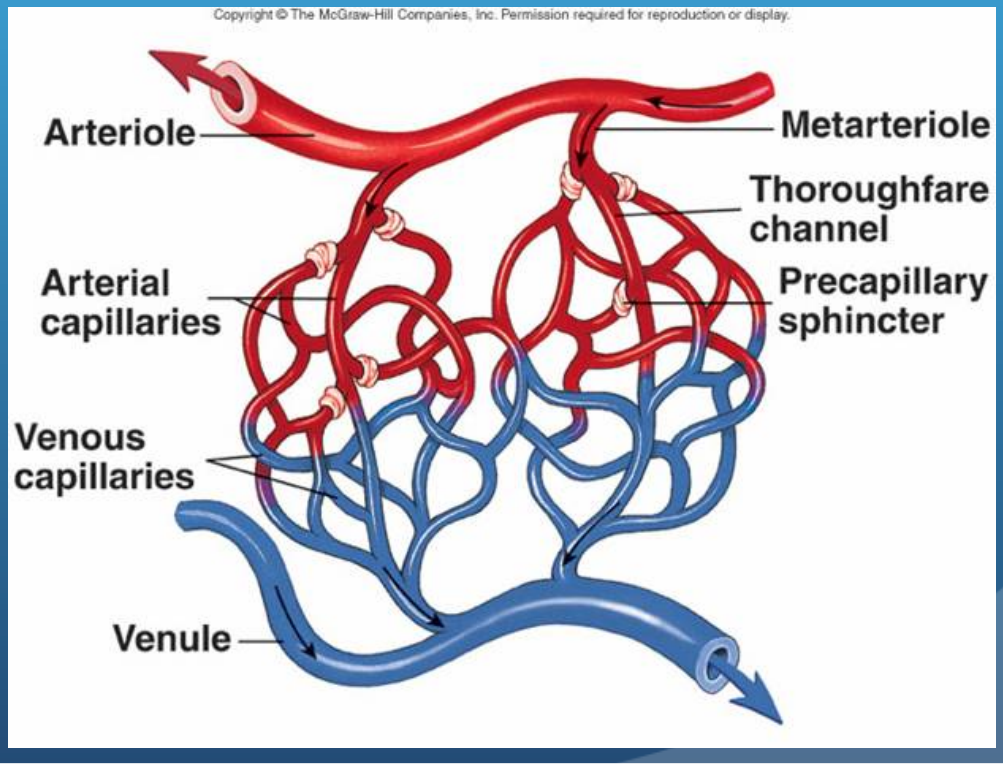
ANIMATION

C. Arterioles

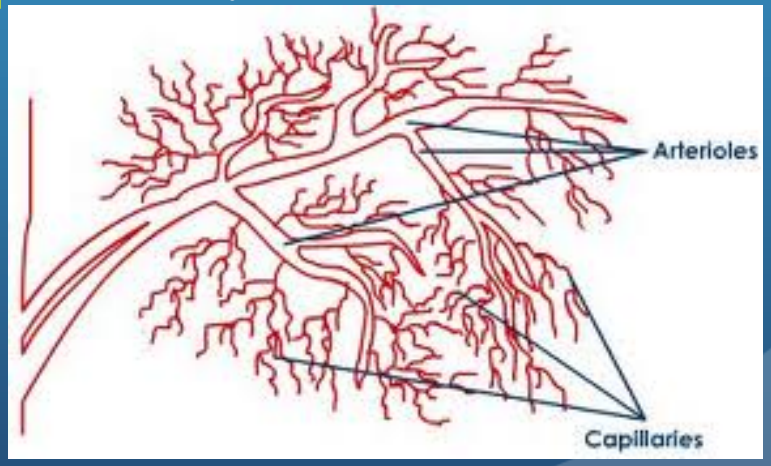
1. Arteries branch into arterioles.
2. About 0.2 mm in diameter or smaller.
3. Mostly smooth muscle to allow for more control of the arteriole.

II. Capillaries

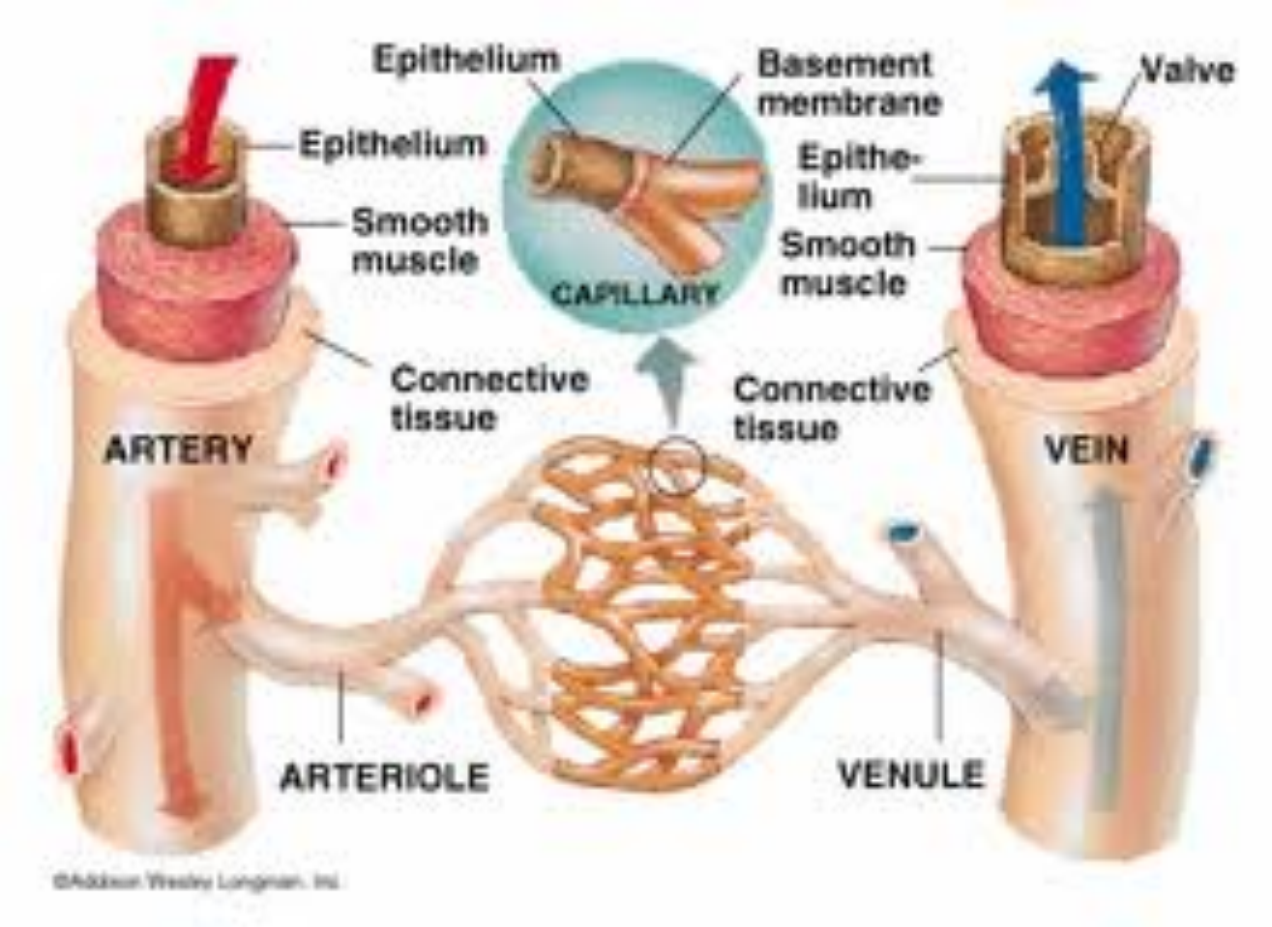
A. Capillaries connect the arterioles to venules, and exchange material with the tissues.



1. Arterioles branch into small vessels called capillaries.
2. Capillaries are very narrow, microscopic tubes.
3. The walls of these tubes are one cell layer thick.
4. Gases and small molecules like glucose exchange across the walls of the capillaries.
5. In a capillary bed some, many, or most of these sphincter muscles may be closed off so that less or more blood flows to that area, as needed
    a. e.g. more blood to muscles when they are working.
    b. e.g. less blood flow to the surface of the skin during hypothermia.



III. Veins and venules



Veins and Venules

A. Carry blood from the tissues to the heart

B. . Veins

1. Walls are thinner than arterial walls.
2. Veins have valves which allow blood to flow only toward the heart when the are open and prevent the backward flow of blood when they are closed.
3. Act as a blood reservoir.

C. Venules

1. Venules join together to form veins
2. Drain the blood from capillaries and then join to form a vein.

IV. Location of Blood

A. Veins contain about 75% of the body's blood.

B. Arteries contain about 20% of the body's blood.

C. Capillaries contain about 5% of the body's blood.

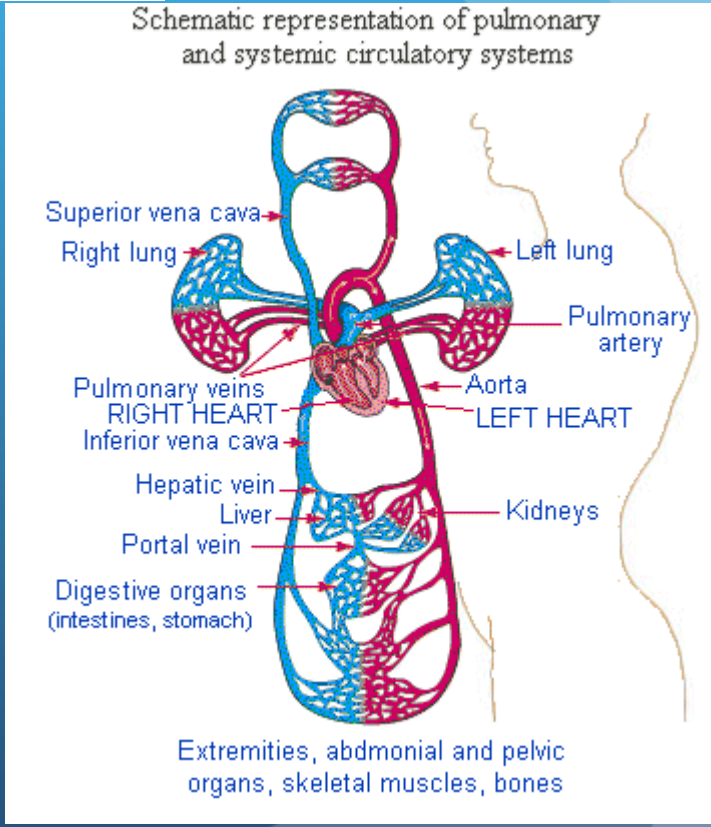
D. There is close to 100,000 km of blood vessels!

Pulmonary and Systemic Circulation

I. Cardiovascular system

A. Divided into 2 circuits:

1. PULMONARY CIRCUIT
2. SYSTEMIC CIRCUIT



Overview of P+S Systems

II. Pulmonary Circuit

A. Path of blood from the heart to/from the lungs.
B. Powered by the right ventricle of the heart.
C. Deoxygenated blood from all tissues collects in the right atrium, is pumped to the right ventricle, then is sent to the pulmonary trunk, which divides into pulmonary arteries, which divide up into the arterioles of the lungs.
D. These arterioles take blood to the pulmonary capillaries, where CO_2 and O_2 are exchanged.
E. The oxygenated blood then enters pulmonary venules, then the pulmonary veins, and finally back to the left atrium.

III. The Systemic Circuit

A. Includes all blood vessels except those in the pulmonary circuit.
B. Blood is pumped to the tissues and organs by the left ventricle of the heart.
C. From the tissues, blood collects in the right atrium via the superior (anterior) vena cava which drains the head and upper body and the inferior (posterior) vena cava which drains the lower body
D. Blood is then pumped to the lungs through the pulmonary circuit

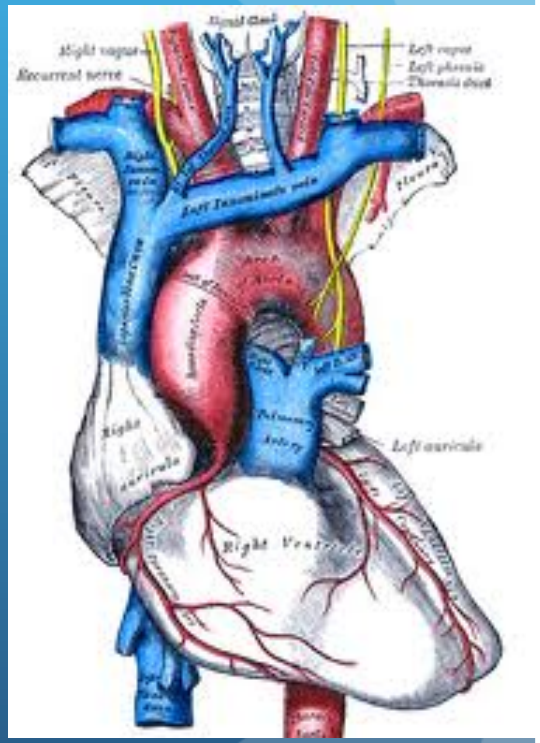
IV. Oxygenated and Deoxygenated blood

A. In the pulmonary system

1. Arteries carry deoxygenated blood.
2. Veins carry oxygenated blood.

B. In the systemic system

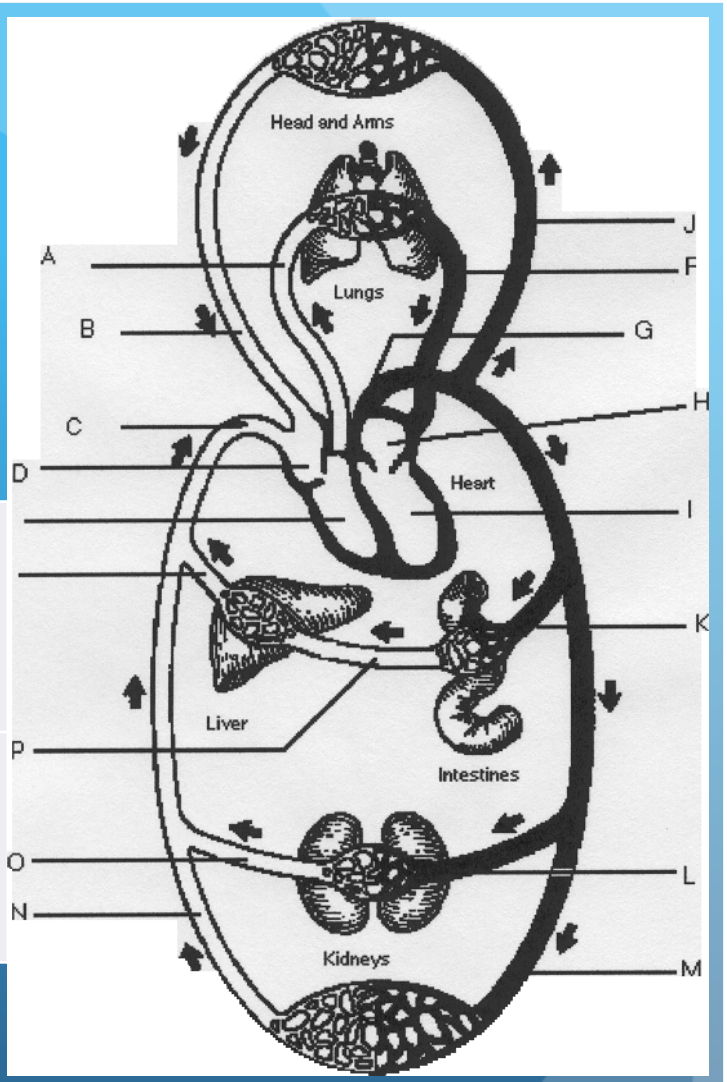
1. Arteries carry oxygenated blood.
2. Veins carry deoxygenated blood.



Significant Vessels

I. Pulmonary Circuit

A	Pulmonary Artery	Takes unoxygenated blood from the right ventricle to the lungs
F	Pulmonary Vein	Brings oxygenated blood to the left atrium from the lungs



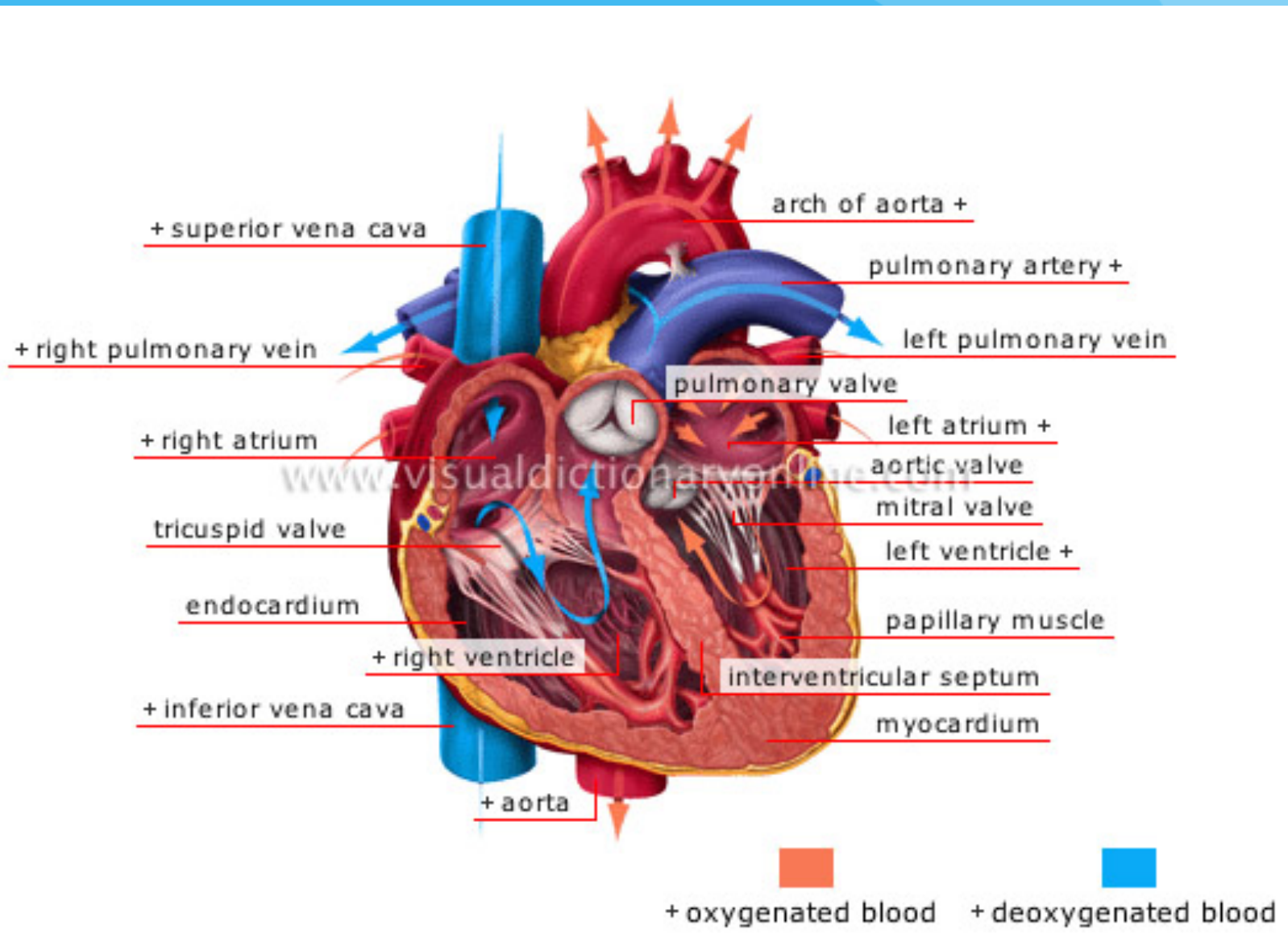
II. Systemic Circuit - Arteries

G	Aorta	Largest artery. Takes blood to major body regions/organs from the left ventricle
J	Carotid Artery	Takes blood to head, subclavian arteries branch off
K	Mesenteric Artery	Takes blood to the intestines
L	Renal Arteries	Takes blood to the kidneys from the aorta
M	Iliac arteries	Takes blood to the legs from the aorta

III. Systemic Circuit - Veins

B	Superior or Anterior Vena Cava	Largest vein Collects blood from jugular (head) and subclavian (arms) veins Blood enters right atrium
C	Posterior or Inferior Vena Cava	Largest vein Collects blood from lower body Blood enters right atrium
O	Renal vein	Returns blood from the kidneys to posterior vena cava
P	Hepatic Portal Vein	Connects the blood vessels of villi to the liver, carries nutrient rich blood to liver for processing *Portal system is a vascular system that begins and ends in capillaries
Q	Hepatic Vein	Returns blood from the liver to posterior vena cava
N	Iliac veins	Returns blood from the legs to posterior vena cava

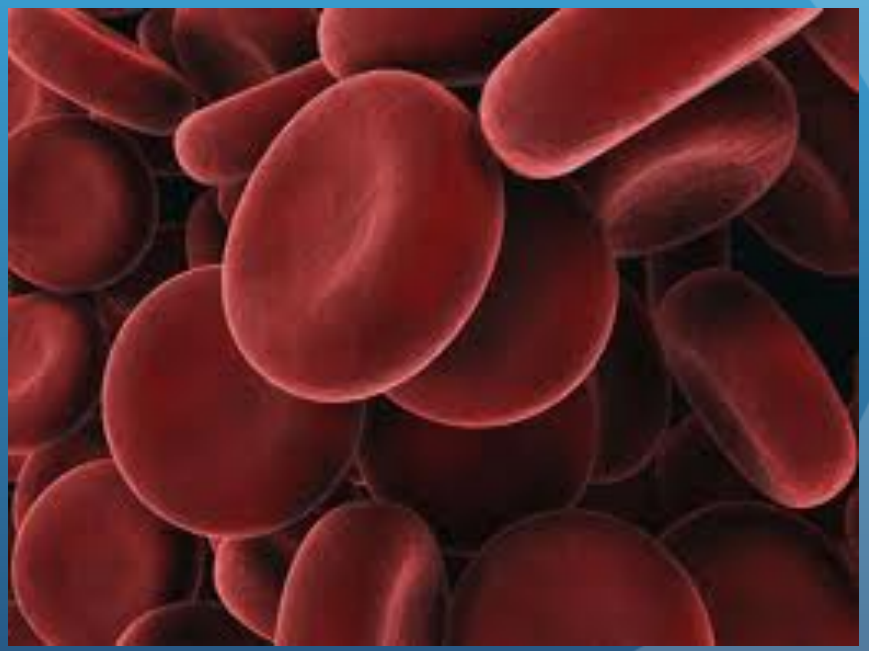
IV. Chambers of the Heart



D	Right Atrium	Pumps blood into right ventricle
E	Right Ventricle	Pumps deoxygenated blood to lungs
H	Left atrium	Pumps blood into left ventricle
I	Left ventricle	Pumps oxygenated blood into the aorta

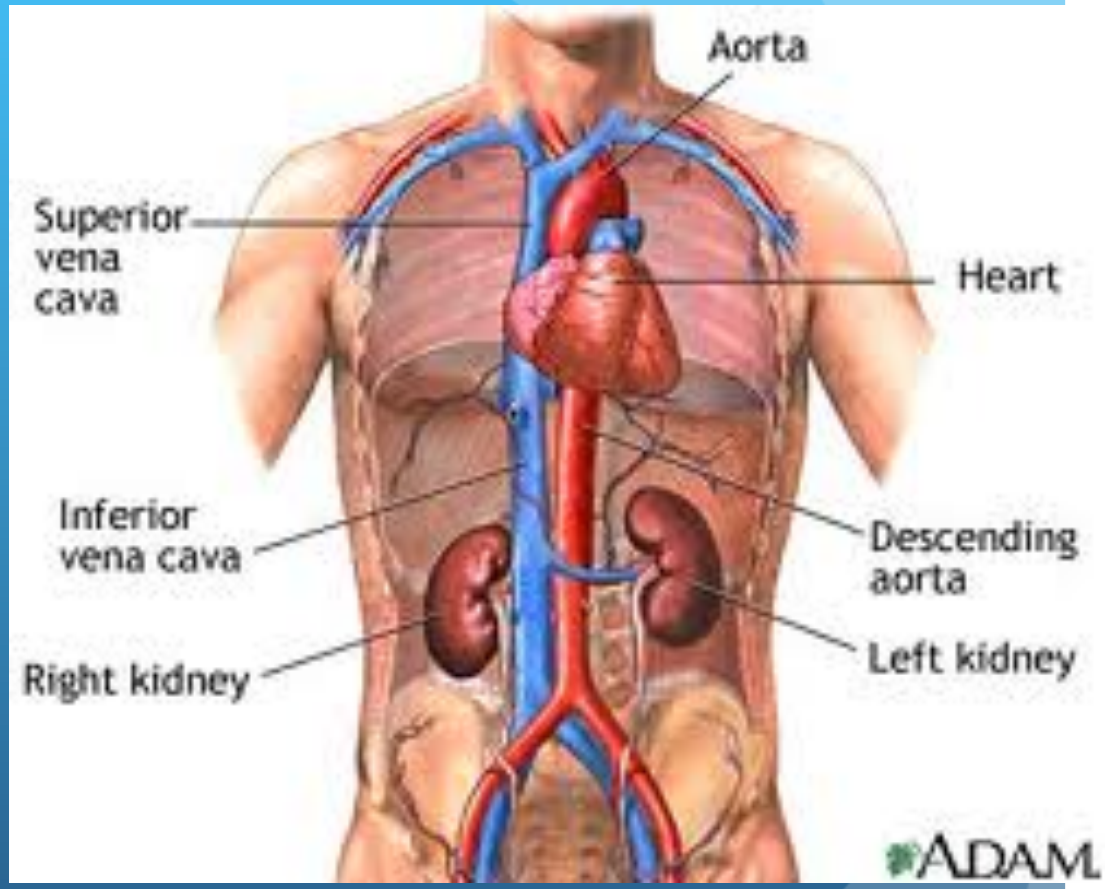
Path of a blood cell

1. You should also be able to describe the flow of blood around the body through any major organ!



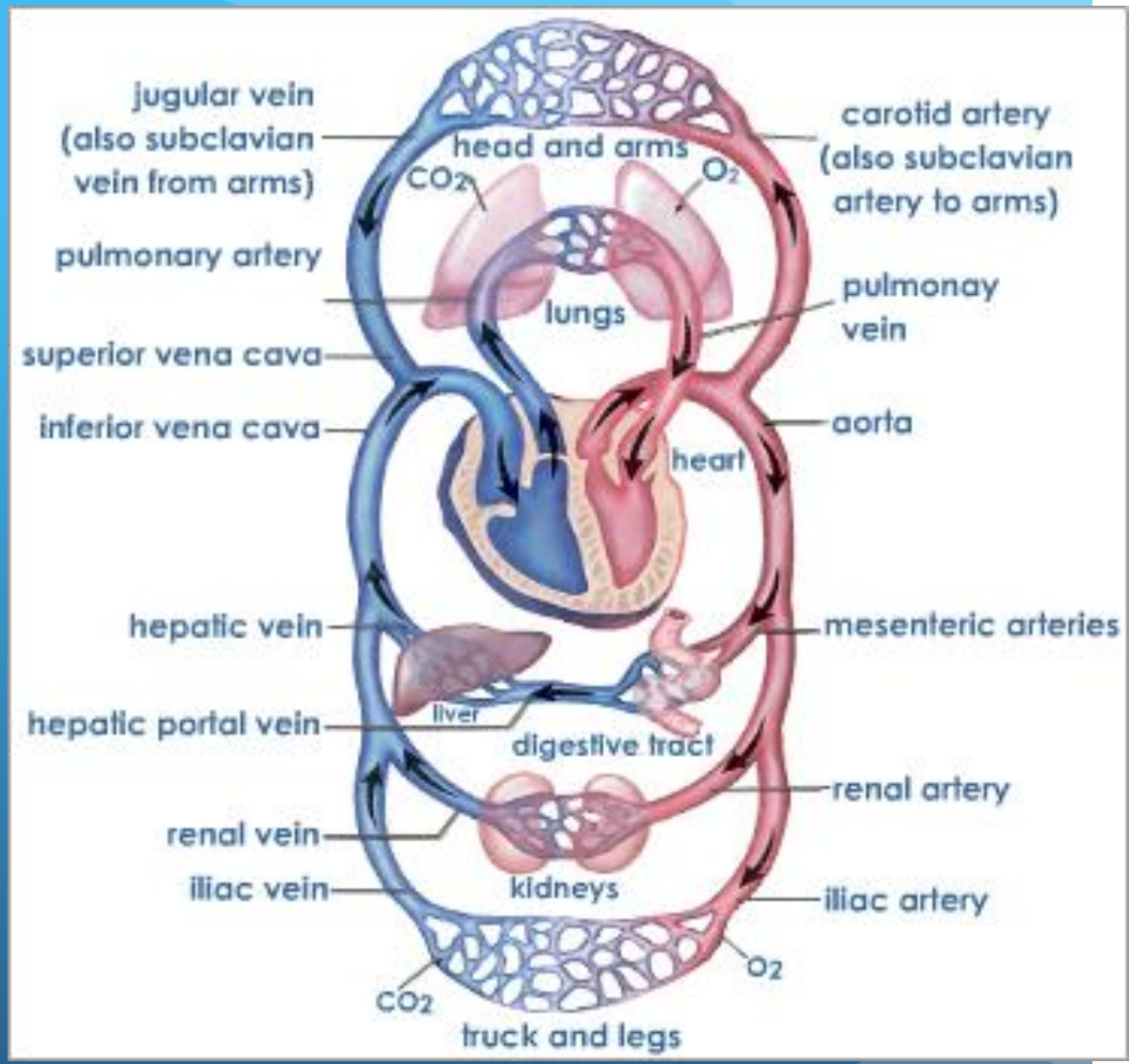
2. Path of blood to kidneys

a. Left ventricle *to* aorta *to* renal artery *to* renal arterioles *to* capillaries *to* venules *to* renal vein *to* inferior venae cava *to* right atrium



3.Path of blood to the intestines

a. Left ventricle *to* aorta *to* mesenteric artery *to* mesenteric capillaries *to* hepatic portal vein *to* hepatic capillaries *to* hepatic vein *to* inferior venae cava *to* right atrium



Adult and Fetal Circulation

I. Fetal Heart

A. Heart develops in 3rd and 4th weeks in uterus.

B. At end of 8 weeks, the embryo's organ systems, including heart, are functioning.

C. During fourth month, fetal heartbeat is loud enough to be heard with stethoscope

Image: Ultrasound showing 4 chamber heart

Video: 12 week ultrasound – you can see beating heart

Differences Between Fetal and Adult Circulation

A. Differences

1. Fetal lungs are NOT used to provide oxygen since it cannot breathe air inside the womb because is immersed in amniotic fluid

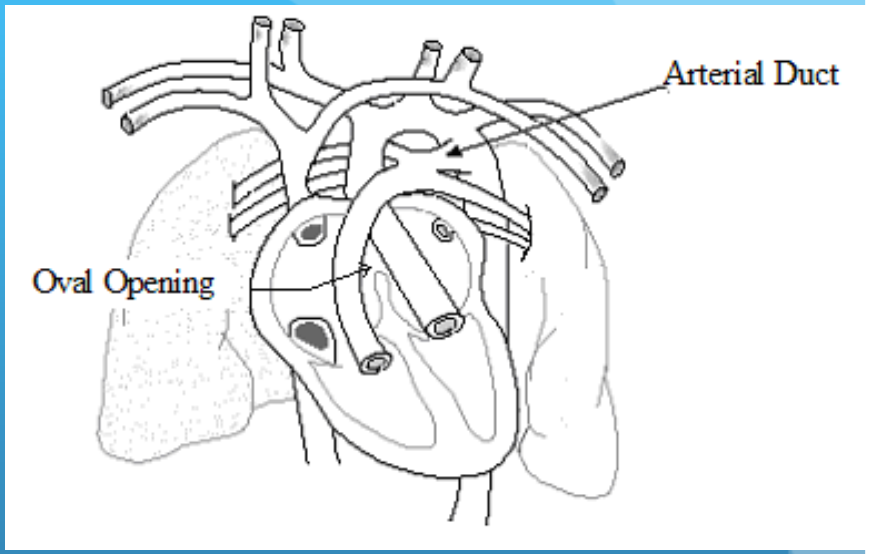
2. Fetus must get all its nutrients from mom, as well as let her take care of its wastes.

Four Features Unique in the Fetus

1. OVAL OPENING (foramen ovale)

a. Opening between the right and left atria, covered by a flap that acts like a valve.

b. Some of the blood from the right atrium is therefore pumped through this flap and into the left atrium, bypassing the pulmonary circuit.

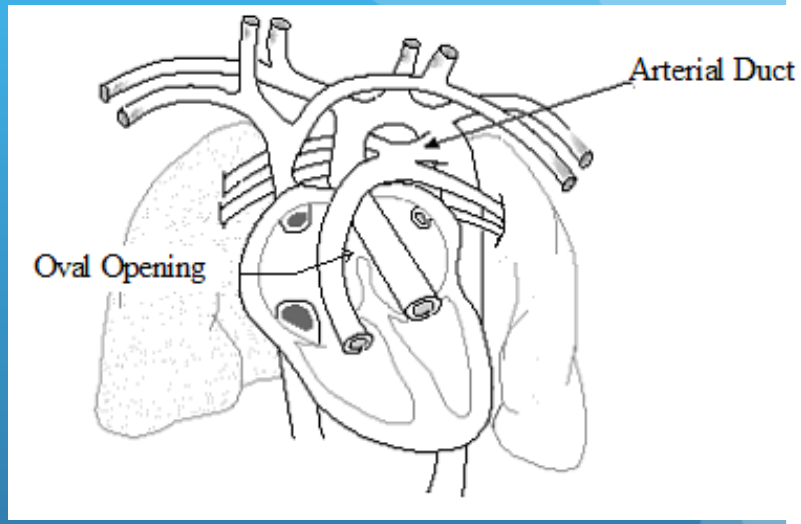


c. If the oval opening doesn't close after birth, it can cause mixing of blood and "blue babies". Correct with open heart surgery.

2. ARTERIAL DUCT (ductus arteriosus)

a. Connects pulmonary artery and aorta.

b. Much of the blood being pumped out of the heart to the lungs will be directed away from the lungs and into the aorta.



c. Like the oval opening, the arterial duct's function is to bypass the pulmonary circuit.

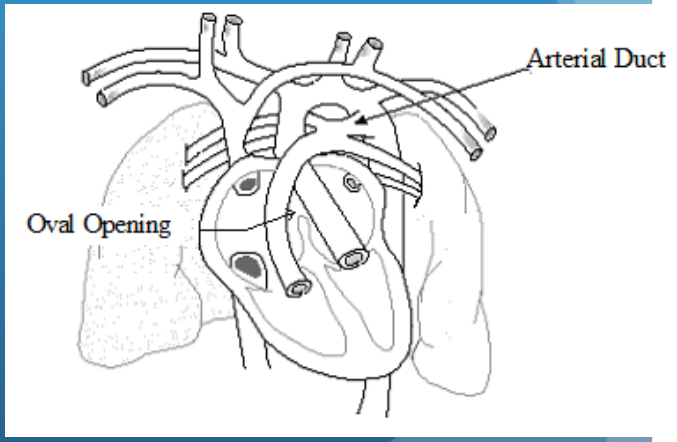
3. UMBILICAL ARTERIES AND VEINS

a. Vessels that travel to and from PLACENTA
   i. Placenta is a membrane shared by the mother and baby across which gases, nutrients, and wastes are exchanged

b. Artery travels toward placenta with waste

c. The umbilical arteries are grafted to the iliac arteries.

d. Vein travels from placenta to fetus with blood rich in O_2 and nutrients

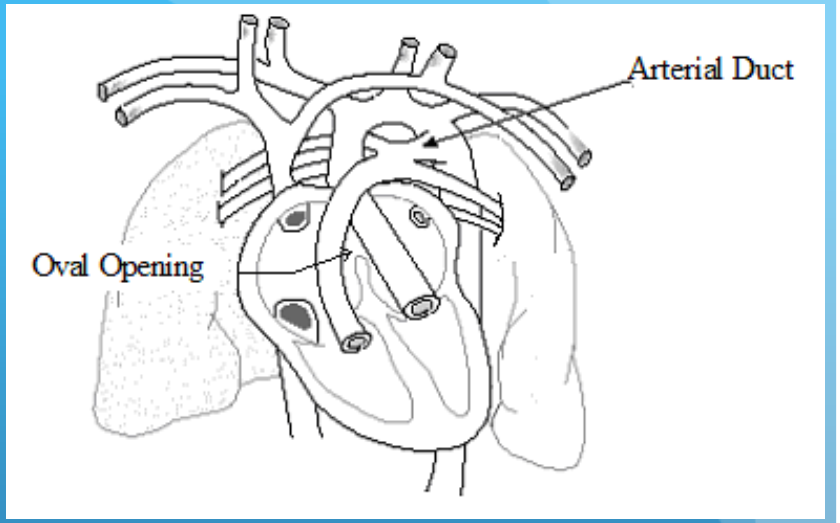


4. VENOUS DUCT (ductus venosus)

a. Connects umbilical vein to the vena cava to bring the blood back to the baby's heart.

b. It attaches right at the babies liver, but bypasses most of the liver.

c. This is why chemicals ingested by the mother can seriously affect the baby



Fetal Circulation Animation

The path of the blood through the fetus

A. Begin with blood collecting in RIGHT ATRIUM
B. From there, blood can go into LEFT ATRIUM through OVAL OPENING plus into RIGHT VENTRICLE through ATRIOVENTRICLE VALVE.
C. RIGHT VENTRICLE to PULMONARY ARTERY. Most of blood will go through ARTERIAL DUCT into AORTA.
D. Aorta to tissue.

E. UMBILICAL ARTERIES lead to placenta, where exchange of gases and nutrients take place.

F. UMBILICAL VEIN carries O_2 rich blood.

G. It enters the VENOUS DUCT, passes through liver.

H. VENOUS DUCT joins with INFERIOR VENA CAVA (it mixes here with deoxygenated blood) and this mixed blood goes back to the heart.

Eating Placenta Video

The Lymphatic System

A. The lymphatic system is another vascular system in your body.

B. It is separate from your cardiovascular system because it has its own veins and capillaries.

C. It ultimately connects back with the cardiovascular system because the fluid from the lymphatic system eventually gets sent back into the bloodstream.

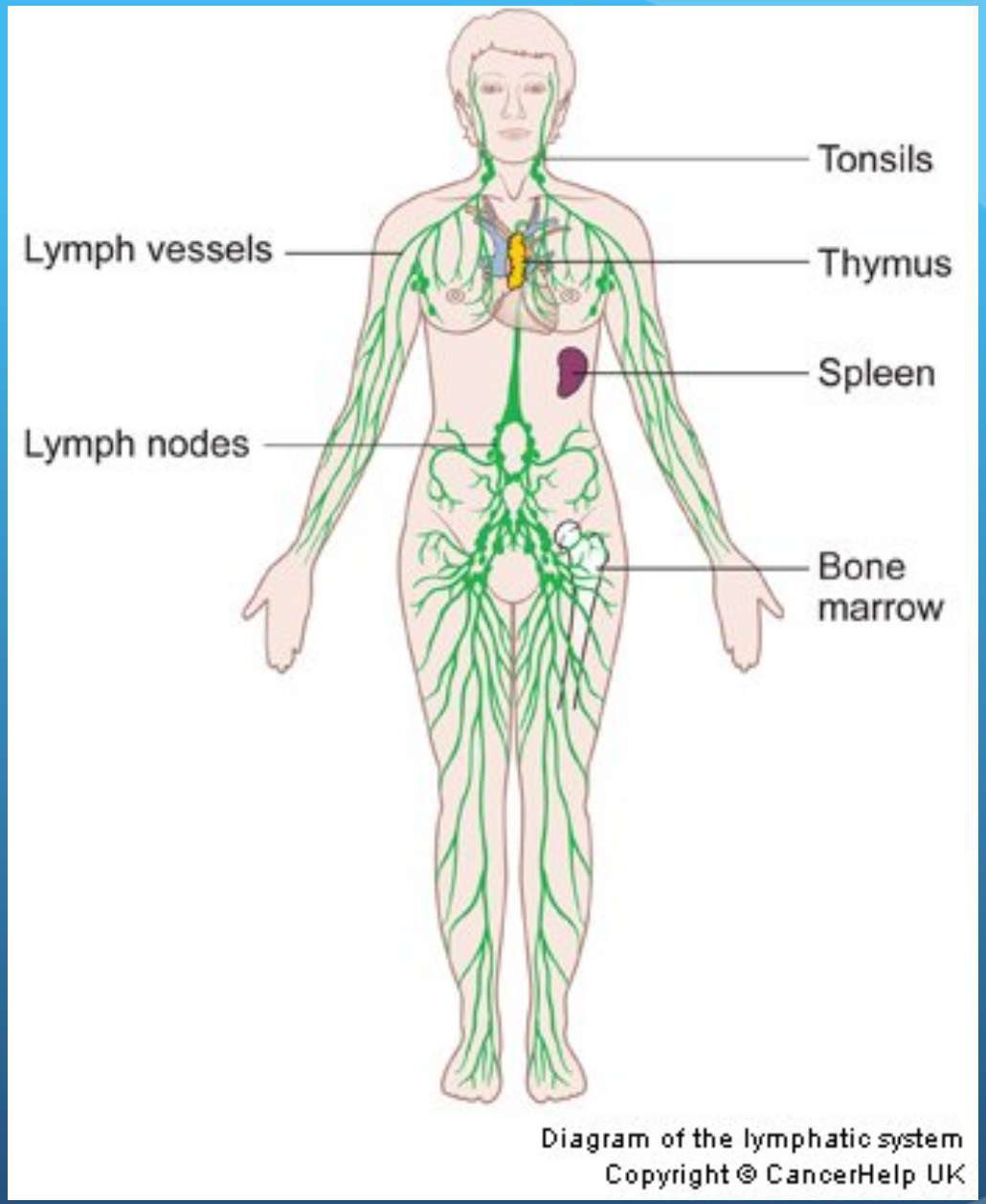


Diagram of the lymphatic system

D. Lymphatic system takes up excess tissue fluid (fluid that surrounds cells and tissues) from the tissues and moves into the larger lymphatic vessels and through the lymph nodes and eventually enters the blood through the veins in the neck region.

E. Lymph has no pump of its own so its flow depends on pressure from the blood system and the massaging effect of the muscles.

F. It is a one-way system that starts in the tissues and empties into the cardiovascular system.

II. Lymph

A. Once fluid enters the lymph vessels it is called **LYMPH**.

B. Lymph resembles **plasma**, but is more diluted (about 5% of proteins and 1% of salts)

C. Formed from bits of blood and other body liquids, called **interstitial fluid**, that collect in the spaces between cells.

D. Some of the interstitial fluid goes back into the body through the capillary membrane, but most enters the lymphatic capillaries to become lymph.

E. Along with this interstitial fluid, the lymph also picks up any particles (cell debris, fat globules, etc) that are too big to be absorbed through the capillary membrane.

F. Lymph contains LYMPHOCYTES which are a type of white blood cell.

III. Main Functions of the Lymphatic System

A. **Transport** of excess tissue fluid back to cardiovascular system

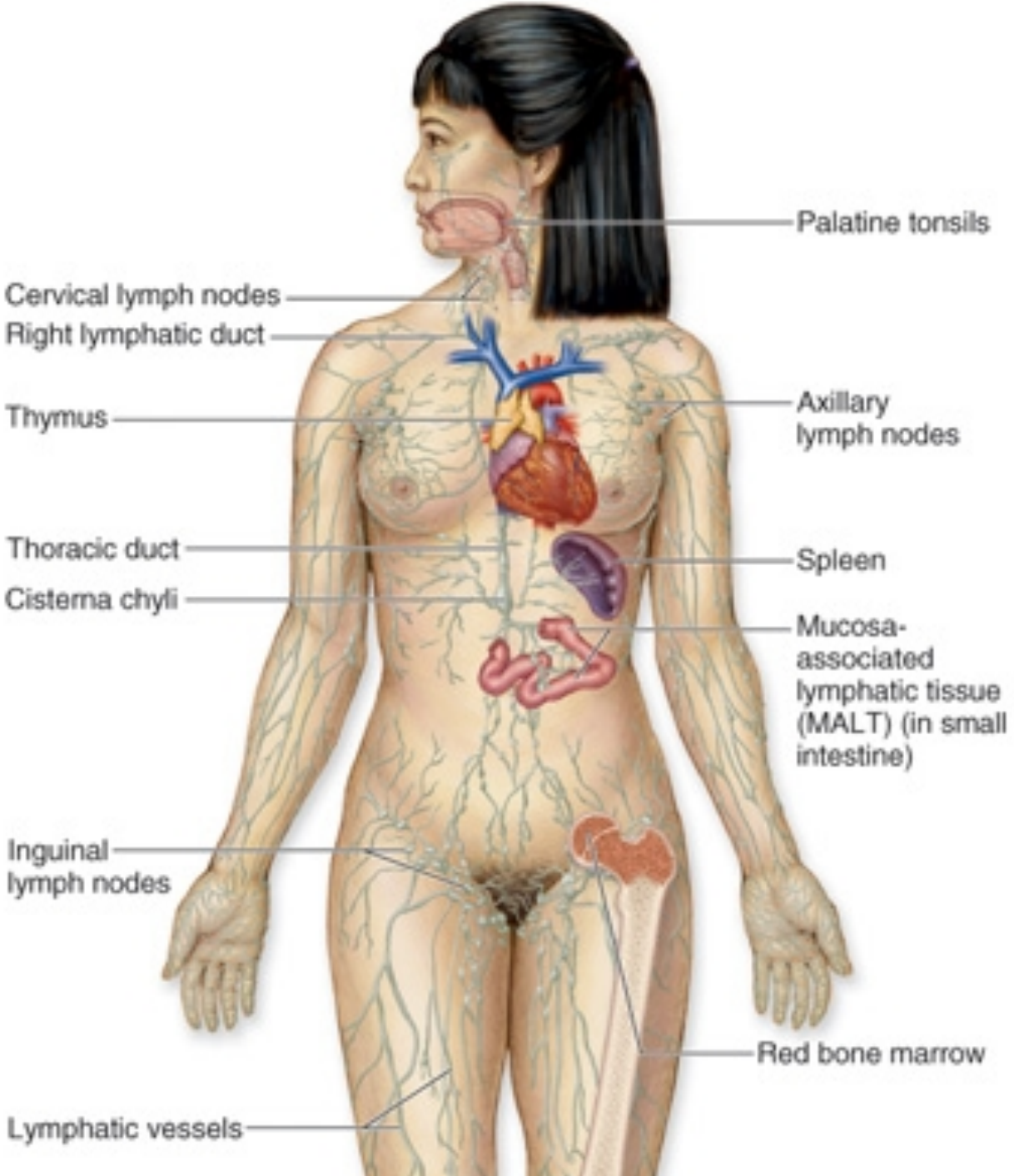
B. **Absorption** of **fat** from the intestine and transport to blood

C. Fighting **infection**

1. **Cleansing lymph**
2. **Produce lymphocytes** (a type of white blood cell)
3. Some lymphocytes produce **antibodies**

V. Components of the Lymphatic System

A. No lymph "arteries" since there is no "pump" in this system
B. Lymph capillaries take up cell fluids
C. Lymph capillaries drain into lymph veins which have valves for one-way flow
D. Lymph veins join to two main trunks
    1. RIGHT LYMPHATIC DUCT
        a. Drains the upper right portion of the body and empties into the right subclavian vein
    2. THORACIC DUCT
        a. Drains the rest of the body and drains into the left subclavian vein


Palatine tonsils
Cervical lymph nodes
Right lymphatic duct
Thymus
Axillary lymph nodes
Thoracic duct
Spleen
Cisterna chyli
Mucosa-associated lymphatic tissue (MALT) (in small intestine)
Inguinal lymph nodes
Red bone marrow
Lymphatic vessels

V. Other Parts of the Lymphatic System

A. Lacteal
   1. Blind ends of lymph vessels in villi of the small intestine.
   2. Products of fat digestion enter here.

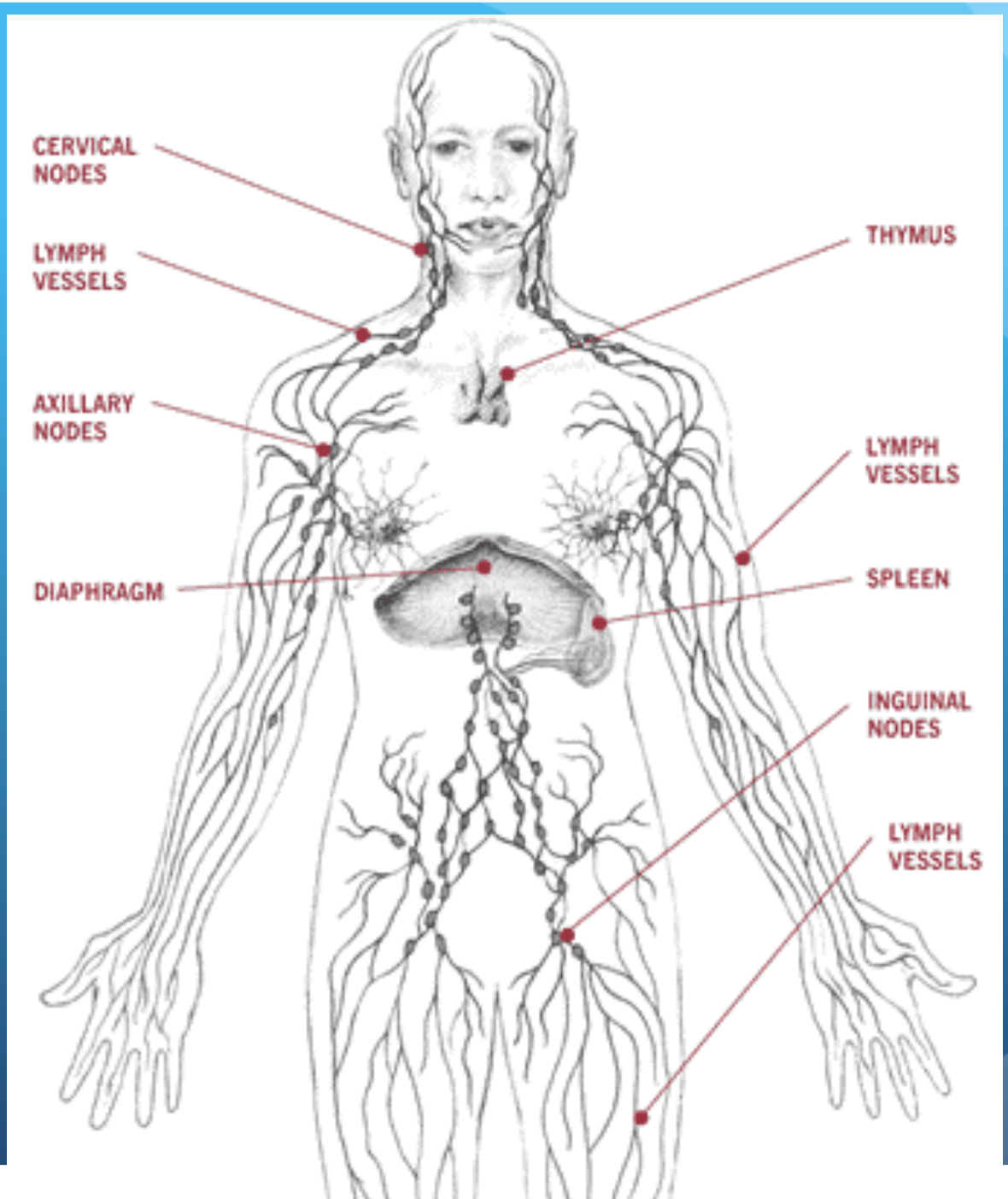
B. Lymph Nodes
   1. Small oval or round structures that occur along strategic places on lymph vessels.
   2. They produce and store lymphocytes
   3. These fight infection by producing antibodies which attach to and "flag" or deactivate foreign proteins
   4. Filter lymph of damaged cells, bacteria and spreading cancer cells as well as debris.

C. Spleen

1. Located behind the stomach.
2. Contains white blood cells and stores blood.

D. Thymus Gland

1. Located in the upper thoracic cavity.
2. Functions in production and maturation of some lymphocytes.
3. Decreases in size with age.

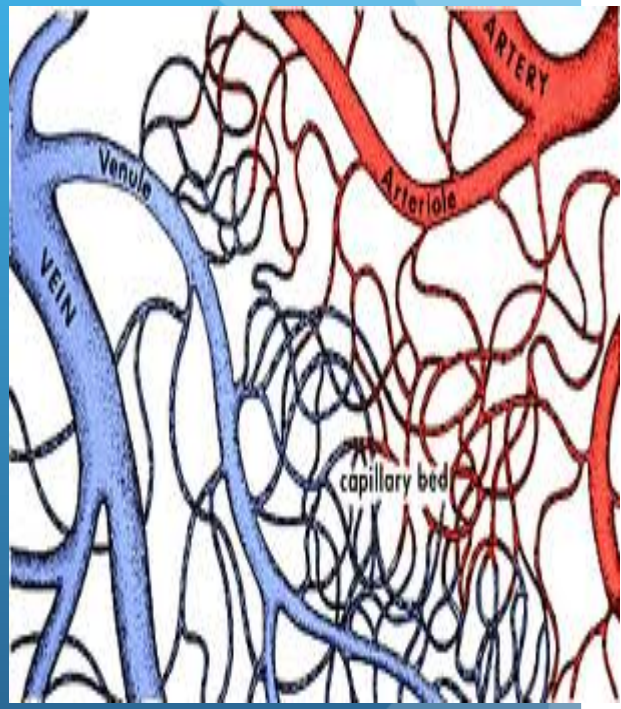

CERVICAL NODES
LYMPH VESSELS
AXILLARY NODES
DIAPHRAGM
THYMUS
LYMPH VESSELS
SPLEEN
INGUINAL NODES
LYMPH VESSELS

Capillary – Tissue Fluid Exchange

I. Exchange of Gases

A. Oxygen

1. 95% is carried by oxyhaemoglobin (HbO_2)
   a. 200 million hemoglobin molecules per RBC
   b. Each hemoglobin carries four oxygen molecules



2. 5% dissolved in plasma

ANIMATION

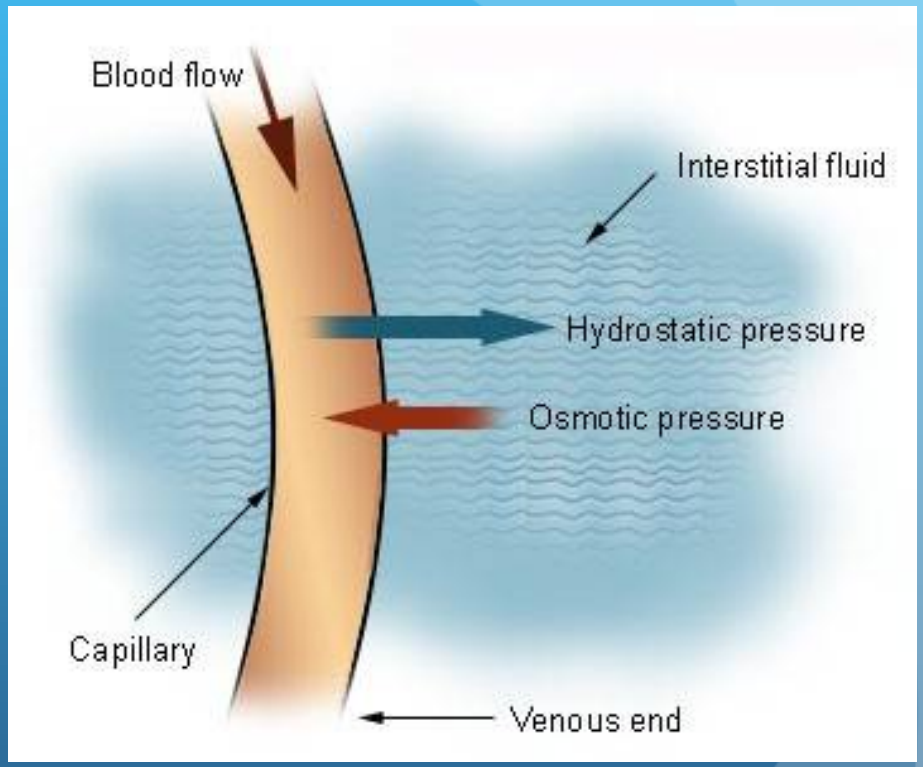
B. Carbon dioxide (CO_2)
   1. 9% dissolved in plasma
   2. 27% picks up CO_2 to form carbaminohemoglobin ($HbCO_2$).
   3. 64% of CO_2 is transported as bicarbonate ion (HCO_3^-)
      a. It is formed after CO_2 combines with water, forming carbonic acid which then dissociates.
      b. Note the following reaction:
         $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$
      c. The enzyme CARBONIC ANHYDRASE speeds up this reaction.
      d. The H^+ released by reaction changes the blood pH.
      e. To prevent this H^+ is picked up by the globin portion of hemoglobin (to become HHb) so that pH is maintained.

II. Mechanism of Gas Exchange

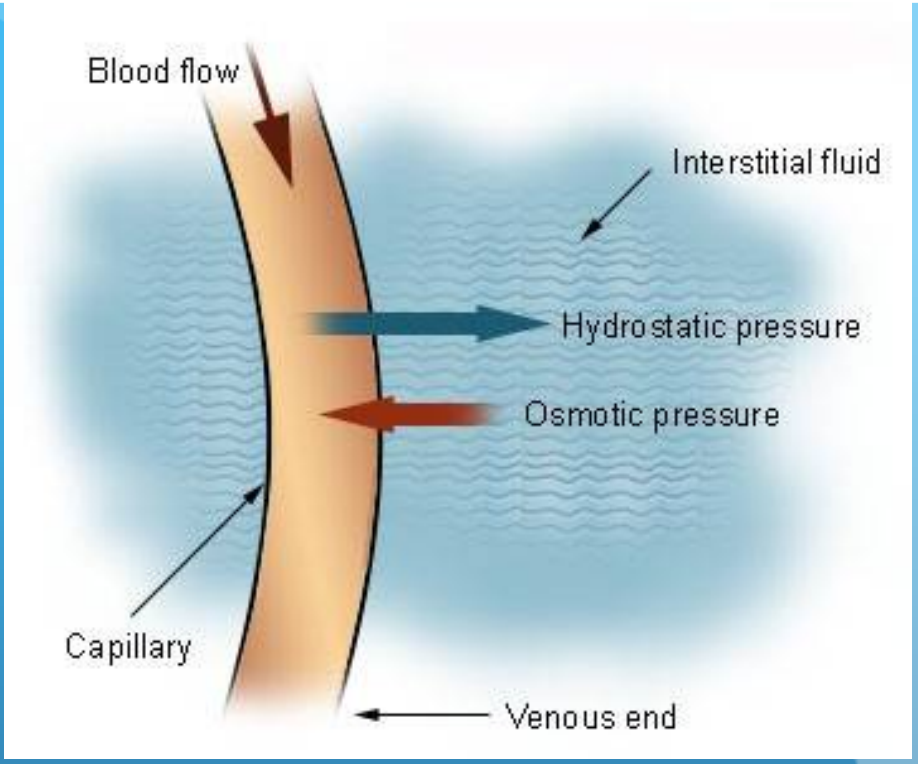
Intro Animation

A. Due to a pressure differential between blood pressure and osmotic pressure.

B. Blood pressure is the pressure of blood in blood vessel would tend to push molecules out of the blood.



1. At arterial side of a capillary bed, blood pressure is (40 mm Hg) HIGHER than blood osmotic pressure (25 mm Hg).
2. Thus plasma constantly "leaks" out through the walls of the capillaries, forming INTERSTITAL FLUID that bathes tissues.
    a. The interstitial fluid contains water, nutrients, hormones, gases, wastes.
    b. Plasma proteins and blood cells are too big so they are left behind in the capillaries.

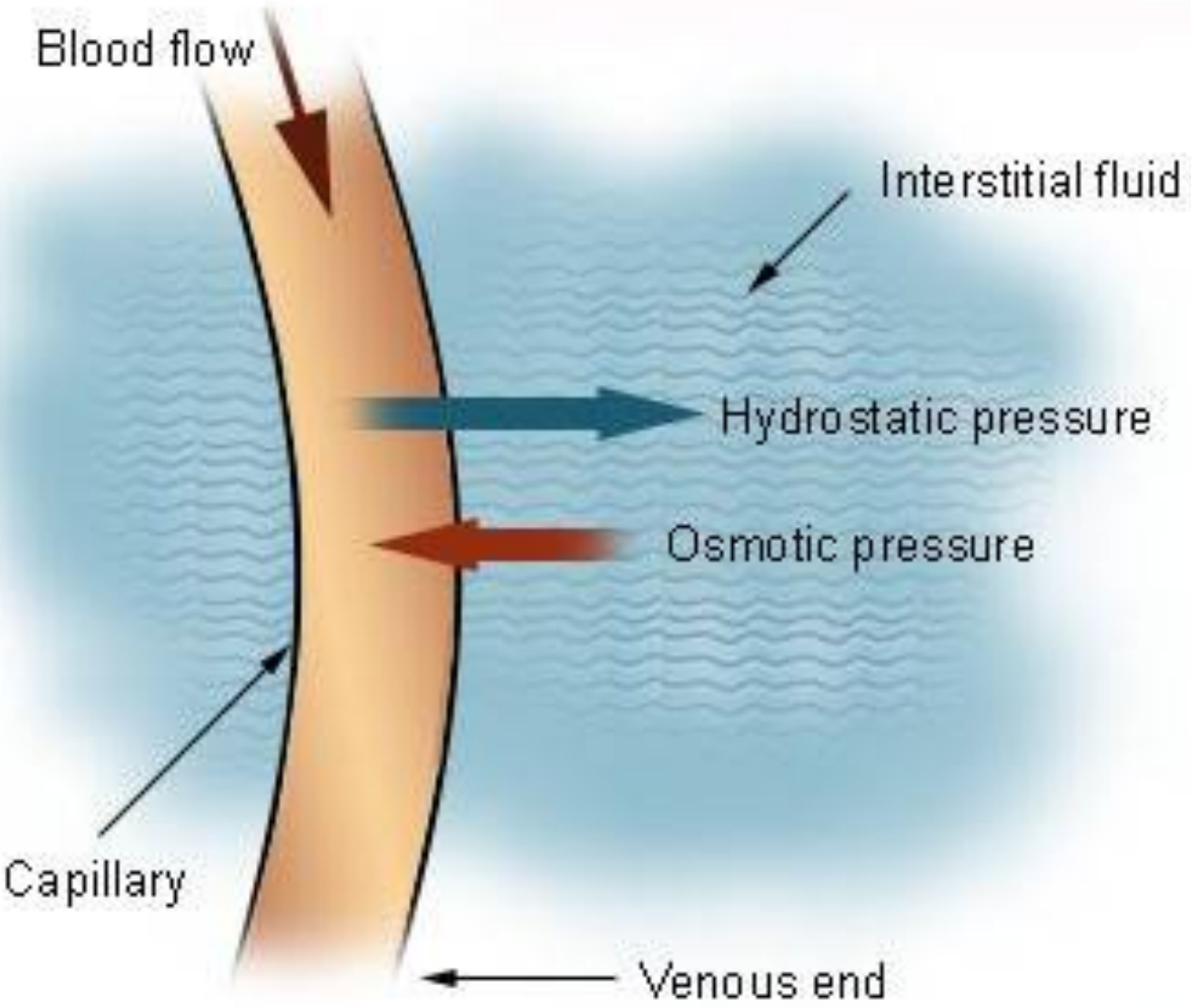


C. Oxygen, sugars and amino acids in the fresh plasma diffuse into/taken up by local cells.

D. CO_2 and waste molecules produced in the tissue cells diffuse out of the tissues and into the interstitial fluid.

E. Osmotic pressure is the opposing force trying to force molecules into the blood.

1. At the venule side of the capillary beds, blood pressure is now reduced (10 mm Hg) whereas osmotic pressure is about the same (25mm Hg).
2. Therefore, water, ammonia, and carbon dioxide laden interstitial fluid is now pulled by osmotic pressure back into the blood vessels tend to enter the bloodstream.
3. Osmotic pressure is basically constant, but blood pressure varies considerable around a capillary bed. This causes some natural movement of molecules.

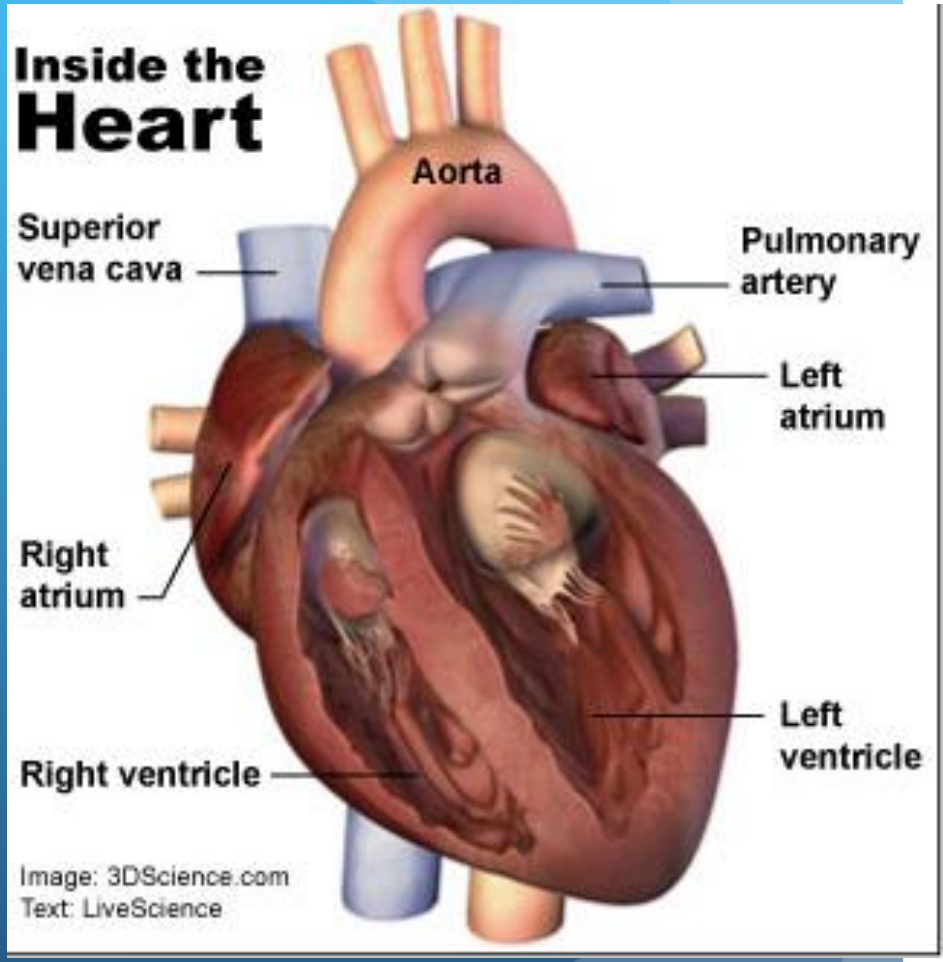

Blood flow
Interstitial fluid
Hydrostatic pressure
Osmotic pressure
Capillary
Venous end

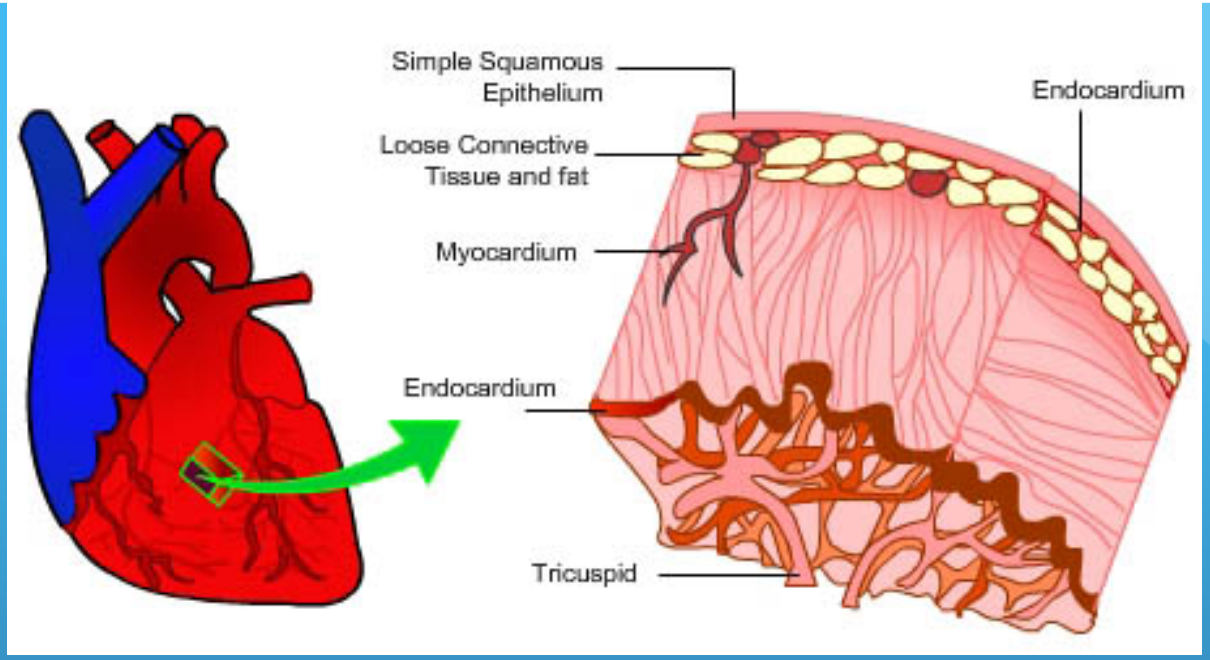
K1. Heart Anatomy

I. <u>Function of the Heart</u>

A. The pump that circulates the **blood** throughout the body.

B. A very muscular organ about the size of a **fist**.



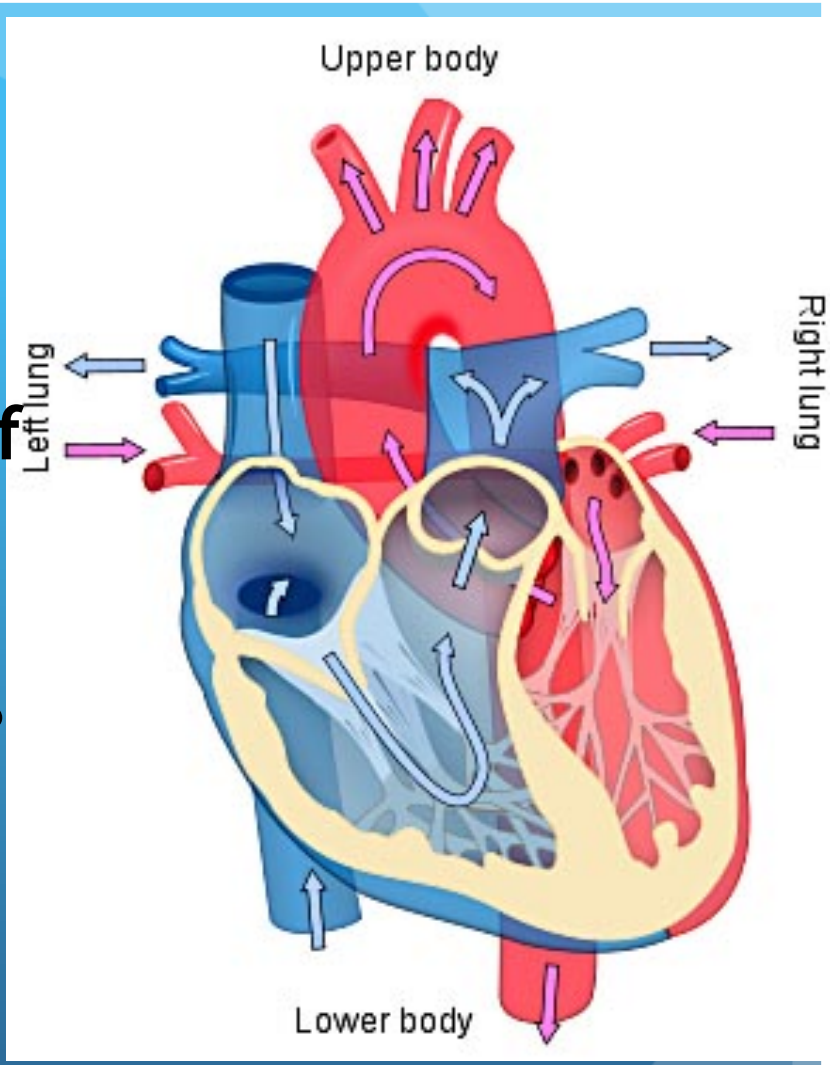


A. Consists of three tissue layers:

1. Outer PERICARDIUM layer composed of epithelial and fibrous tissue.
   a. Pericardium forms a PERICARDIAL SAC that contains the heart.
   b. Has lubricating liquid within the sac.
2. Middle MYOCARDIAL layer composed of cardiac muscle.
3. Inner smooth endothelial layer

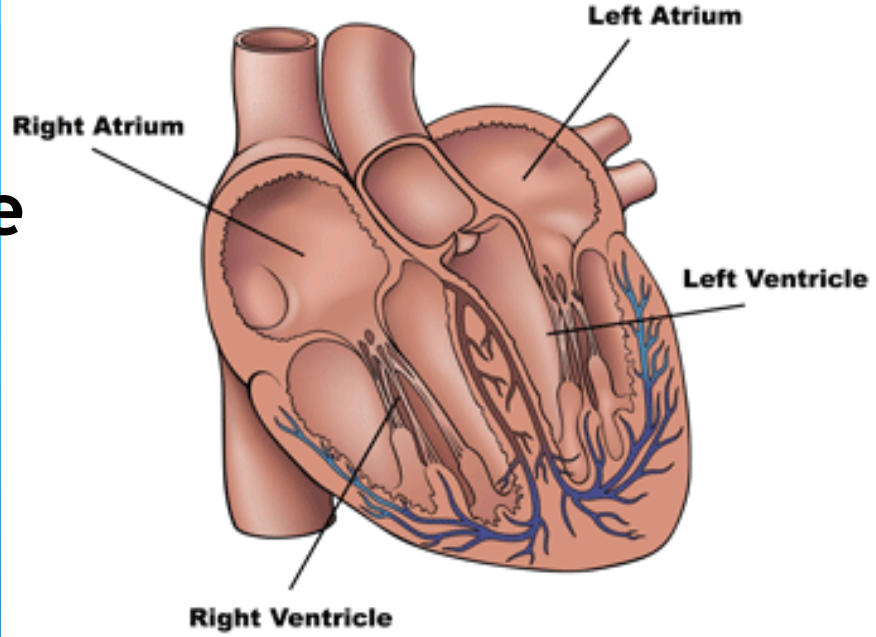
B. The two pumps

1. Right side pumps blood to the lungs.
2. Left side pumps blood to the rest of the body.
3. The left and right side of the heart is divided by the SEPTUM.



C. The 4 chambers

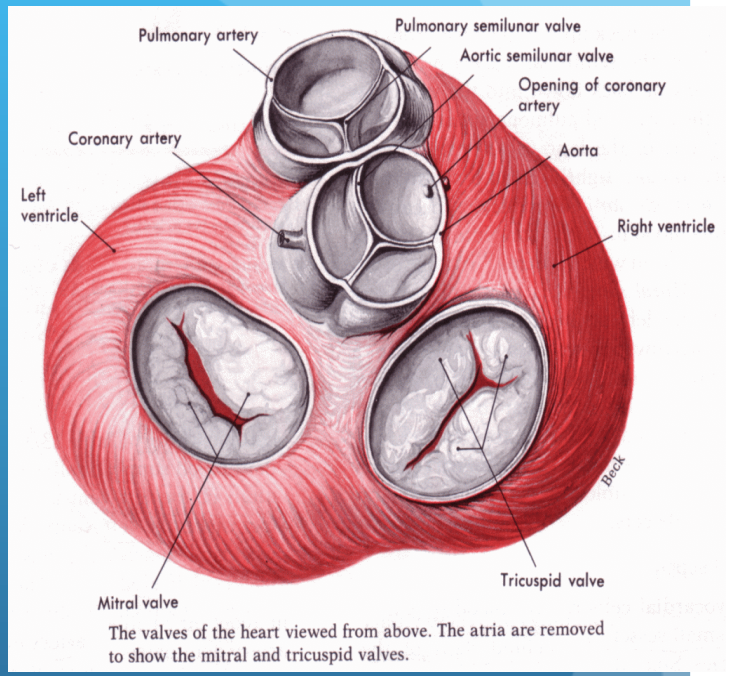
1. There are two chambers on each side of the septum.
2. Smaller chamber, located on the top, is called the ATRIUM (plural = ATRIA).



3. Larger chamber, located on the bottom, is called the VENTRICLE.
    a. Right side is thinner because the lungs are close to the heart.
    b. Left side is thicker because the body is further from the heart

D. Valves

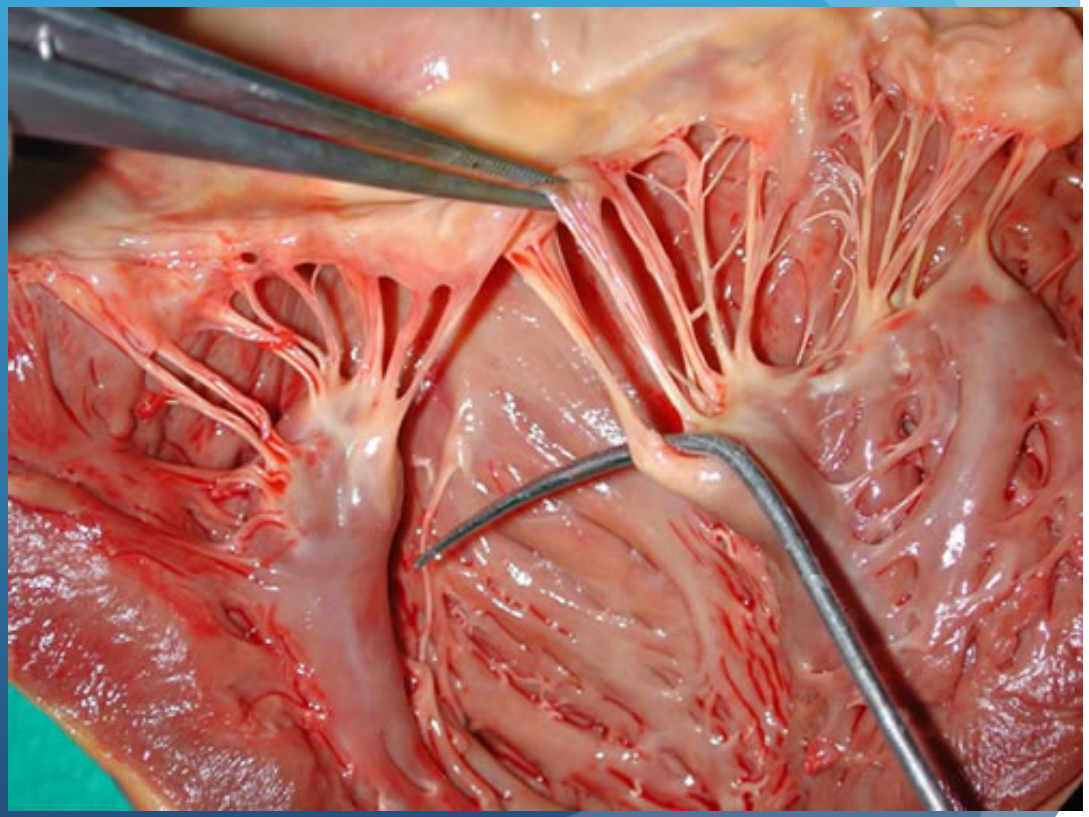
1. ATRIOVENTRICULAR VALVES are located between the atria and ventricles.
    a. Control the flow of blood between the chambers, and prevent blood backflow.
    b. Atrioventricular (AV) valve between the right atrium from the right ventricle is called the TRICUSPID VALVE (has 3 flaps or "cusps").



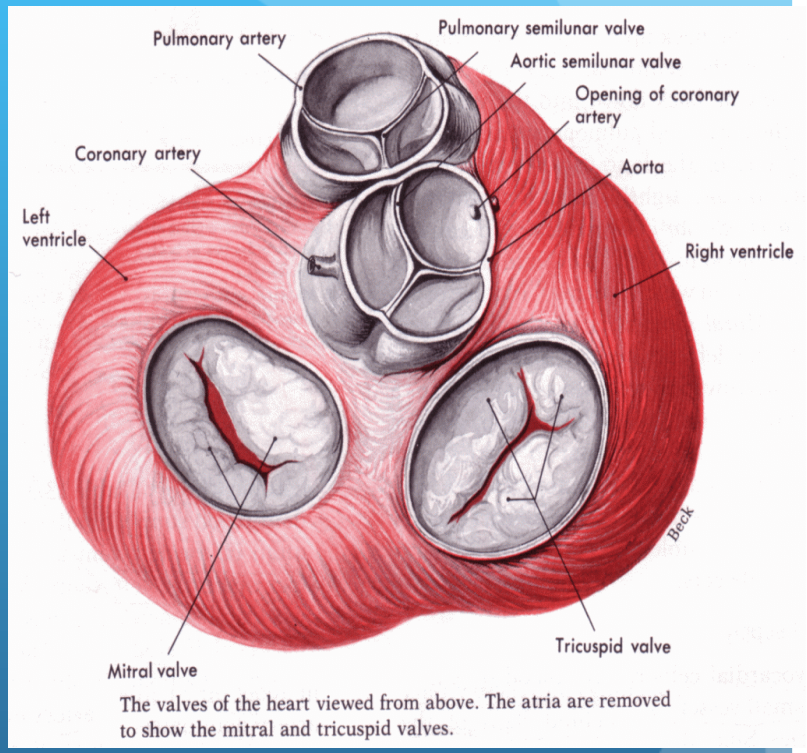
The valves of the heart viewed from above. The atria are removed to show the mitral and tricuspid valves.

    c. Atrioventricular valve between the left atrium and left ventricle is called the BICUSPID VALVE or MITRAL VALVE (has 2 cusps).

2. CHORDAE TENDINAE are very strong, fibrous strings that support the AV valves and prevent them from inverting.



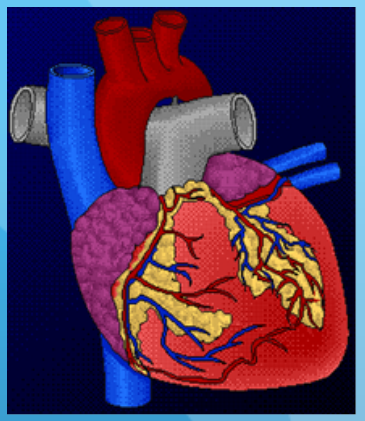
3. SEMILUNAR VALVE are located between the heart and the artery.
   a. Look like half-moons.
   b. Pulmonary semilunar valve is located between the right ventricle and the pulmonary artery.



The valves of the heart viewed from above. The atria are removed to show the mitral and tricuspid valves.

   c. Aortic semilunar valve is located between the left ventricle and the aorta.
   d. No chordae tendinae with semilunar valves.

E. Coronary arteries and veins



1. Vitally important blood vessels that supply blood to the heart muscle itself
2. Heart does not use the blood in its inner chambers.
3. Arteries branch off the aorta just above the aortic semilunar valve, and lie on the outside of the heart.
4. Coronary veins empty into the right atrium.

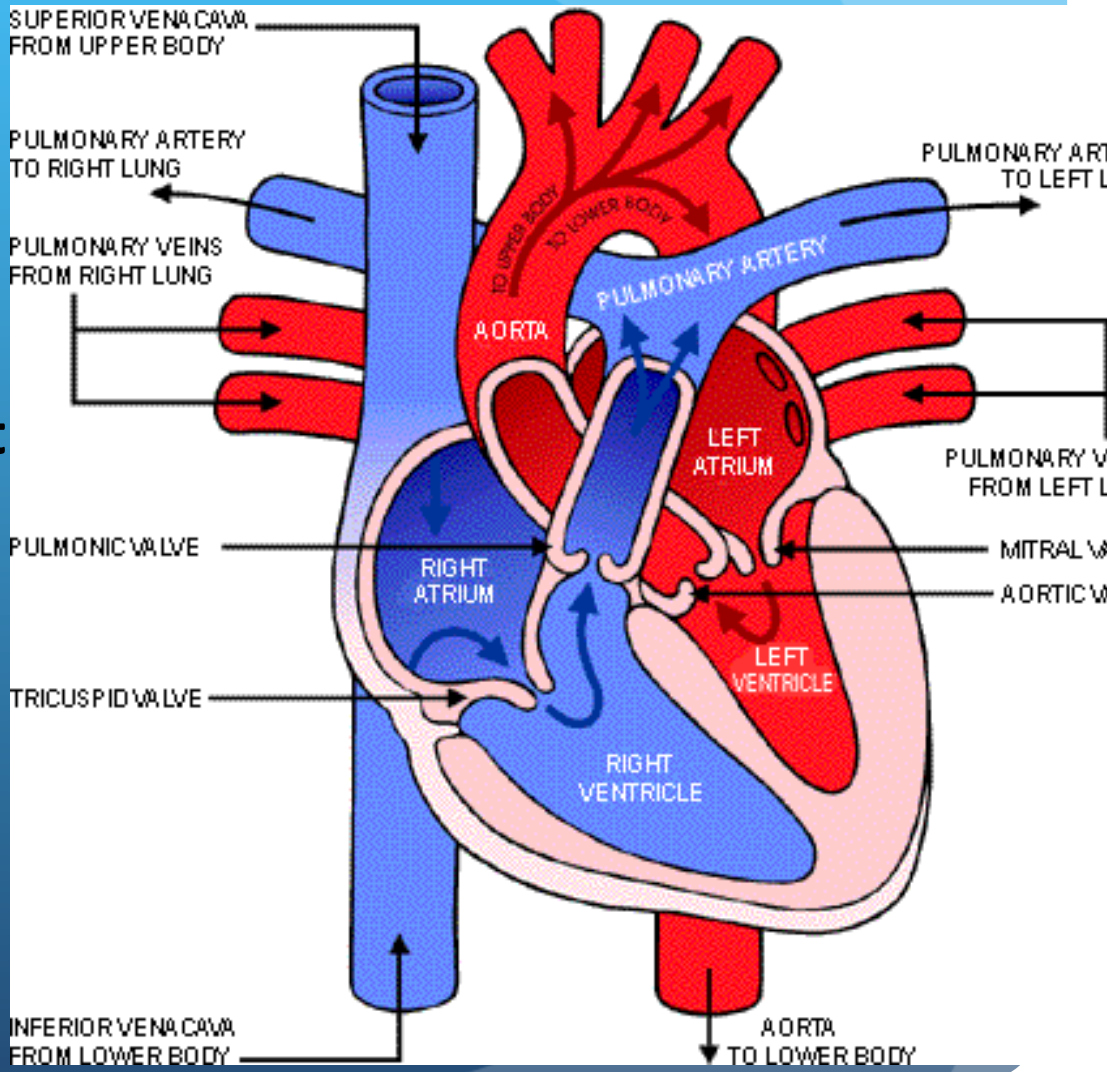
III. Path of Blood Through the Heart

Animation 1
Animation 2

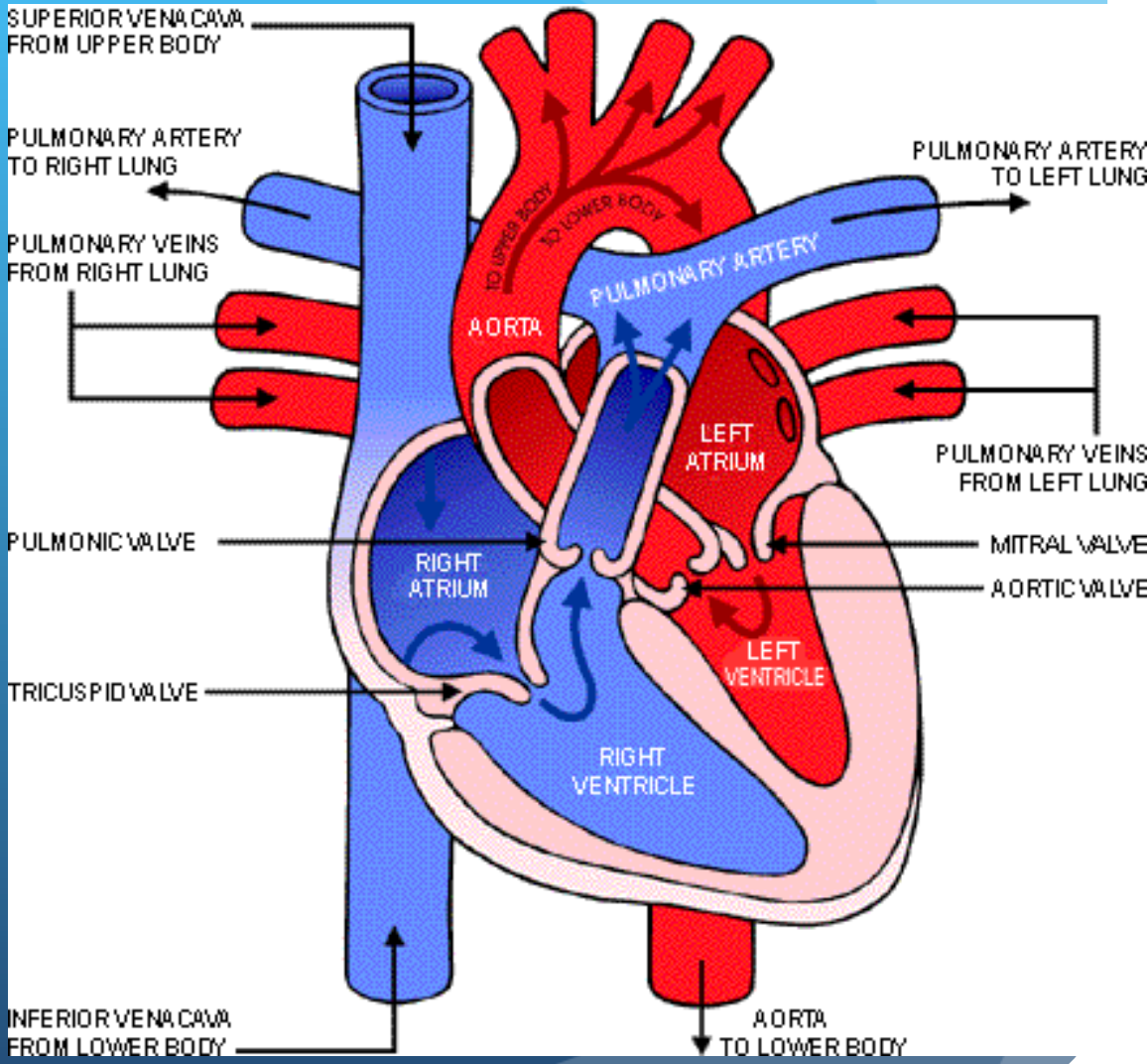
Animation 4

A. Blood low in oxygen ("deoxygenated") enters the right atrium through the **SUPERIOR** and **INFERIOR VENA CAVA**, the body's largest veins.

B. The **RIGHT ATRIUM** contracts, forcing blood through the **TRICUSPID VALVE** and into the **RIGHT VENTRICLE**.



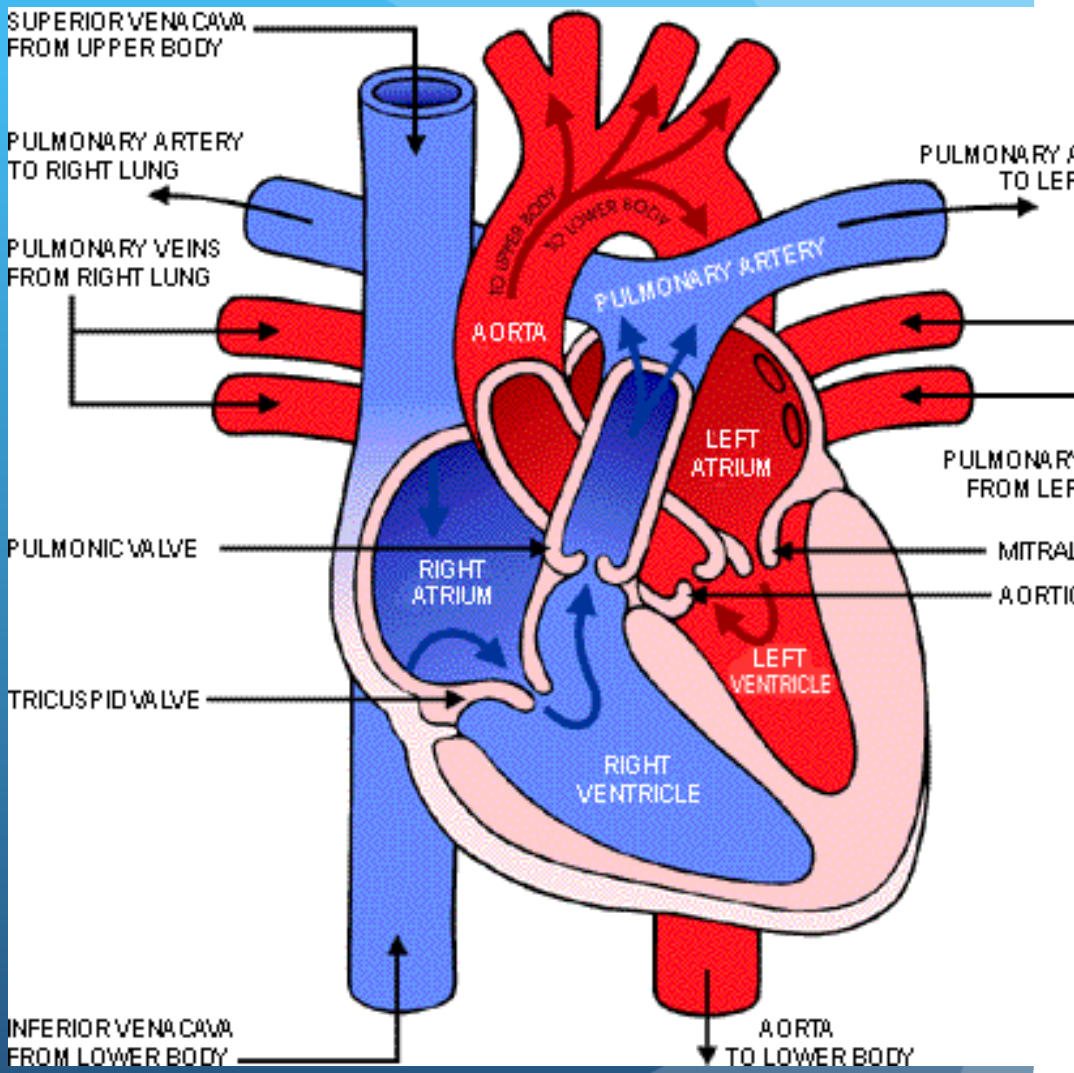
C. The right ventricle contracts, sending blood through the **PULMONARY SEMILUNAR VALVE** and into the **PULMONARY TRUNK**.



D. The pulmonary trunk divides into PULMONARY ARTERIES, which take the deoxygenated blood to the capillaries of the LUNGS.

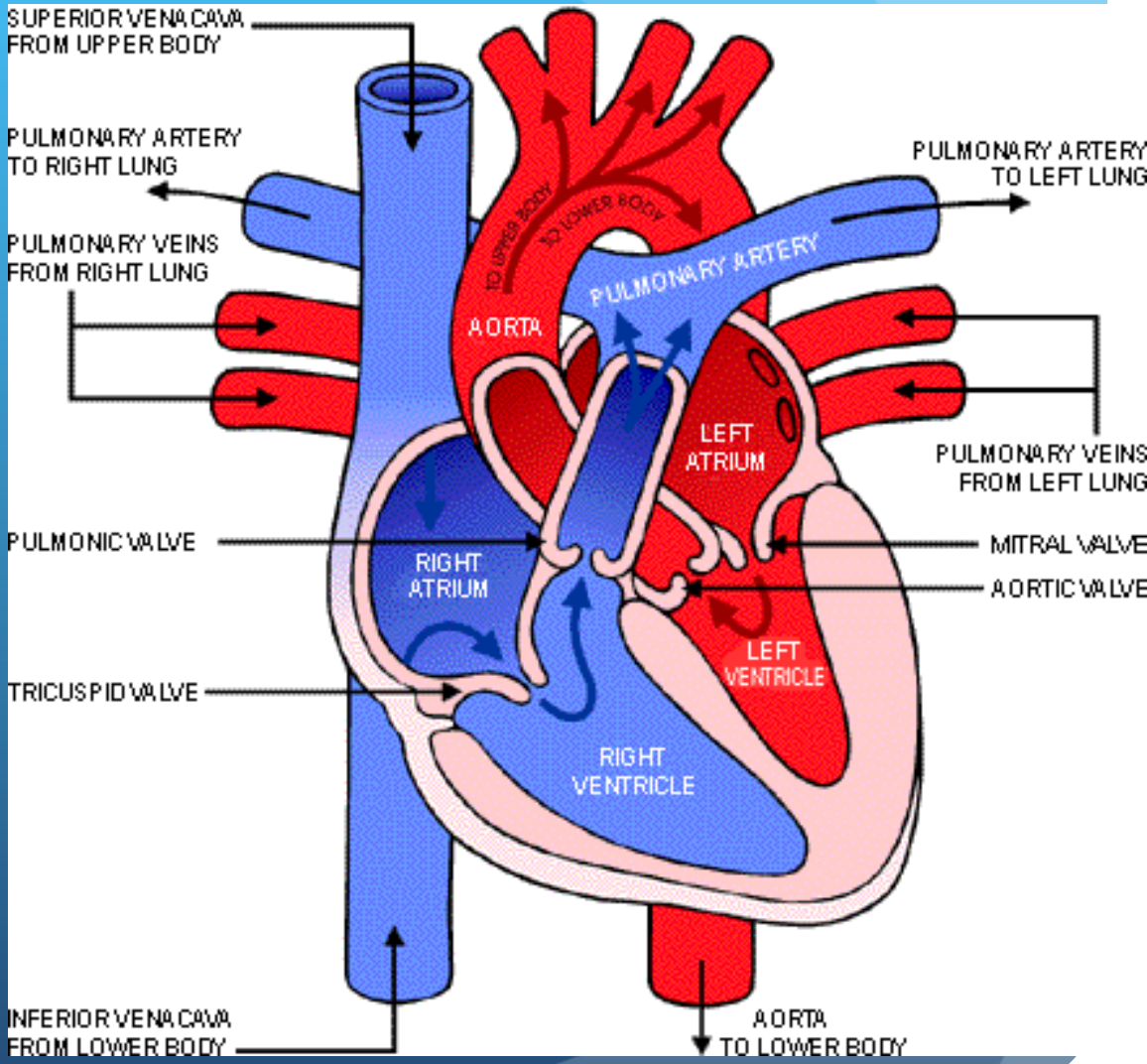
E. At the lungs, carbon dioxide diffuses out of the blood, and, oxygen diffuses into it. The blood is now OXYGENATED.

F. The oxygenated blood feeds into the PULMONARY VEINS, which take it from the lungs to the LEFT ATRIUM



G. The left atrium CONTRACTS, forcing blood through the bicuspid valve into the LEFT VENTRICLE.

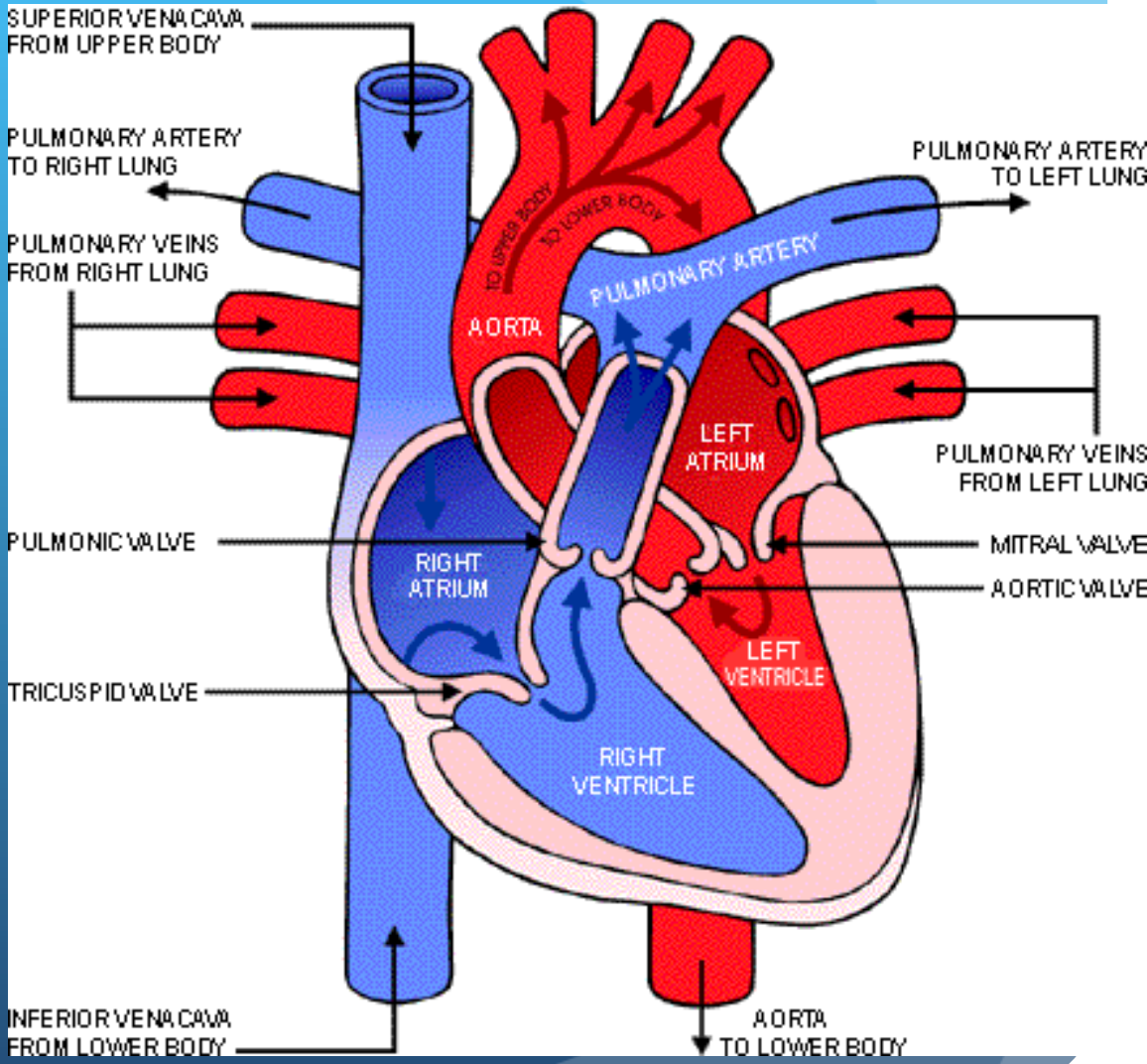
H. The left ventricle CONTRACTS, forcing blood through the AORTIC SEMILUNAR VALVE into the AORTA, the body's largest artery.



I. The aorta divides into smaller arteries, which carry oxygenated blood to all body tissues.

J. Deoxygenated blood NEVER MIXES with oxygenated blood.

K. Two atria contract simultaneously, and the two ventricles also contract simultaneously.



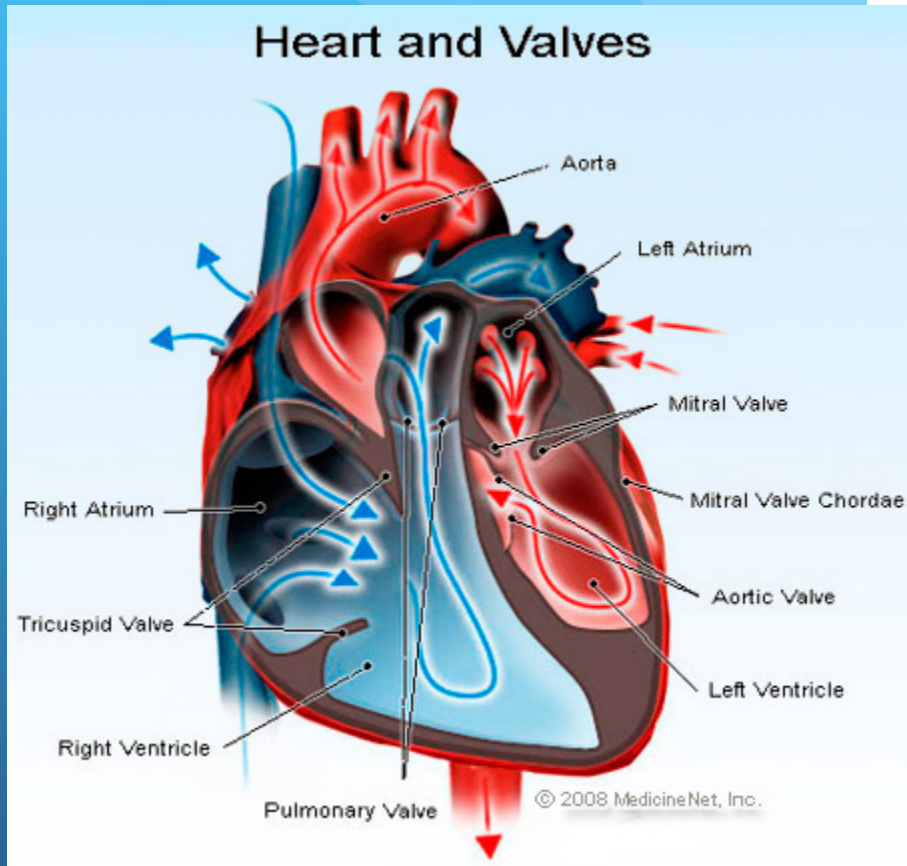
IV. Heartbeat

A. The heartbeat that you can hear can be divided into two phases:

1. **"Lub" is due to the closing of atrioventricular valves.**
   a. **atria contracting**
   b. **ventricles relaxing**
2. **"Dupp" sound is due to the closing of the semi-lunar valves.**
   a. **atria relaxing**
   b. **ventricles contracting**

B. If there is a problem with a valve closing, this can cause HEART MURMURS.

1. Rheumatic fever caused by a bacterial infection can cause a faulty valve (usually the bicuspid valve).
2. Surgery or replacement with an artificial valve can often cure this.



K2. Heart Beat Co-ordination

I. Characteristics of Cardiac Cells

Ted-Ed Heart Pumping

A. Heart muscle tissue can contract on its own

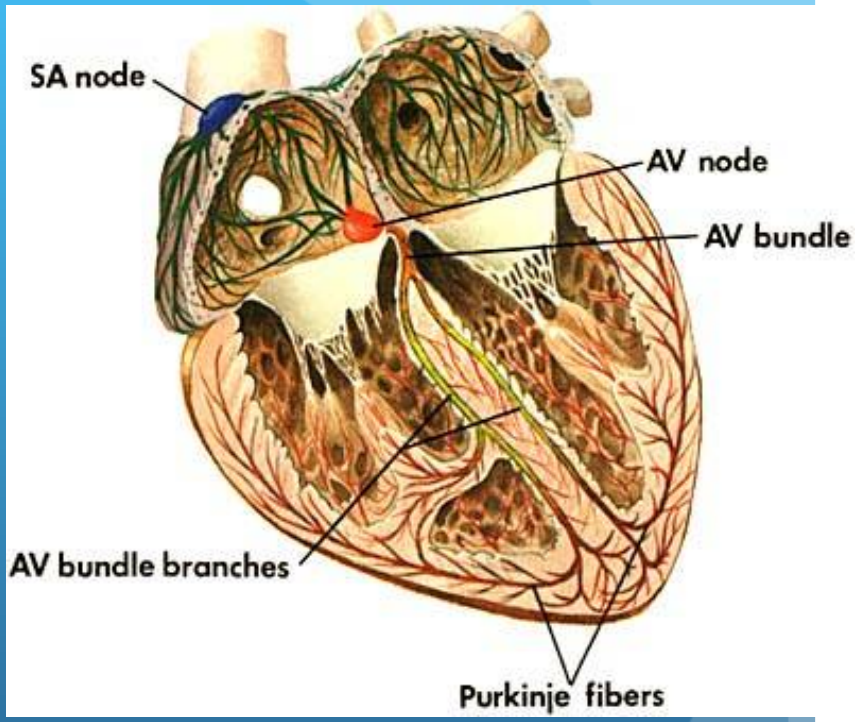
1. Each cardiac cell can contract independently.
2. Will co-ordinate their contractions if the cells are touching.

Video Clip – Dissection - Frog Heart Beating outside body

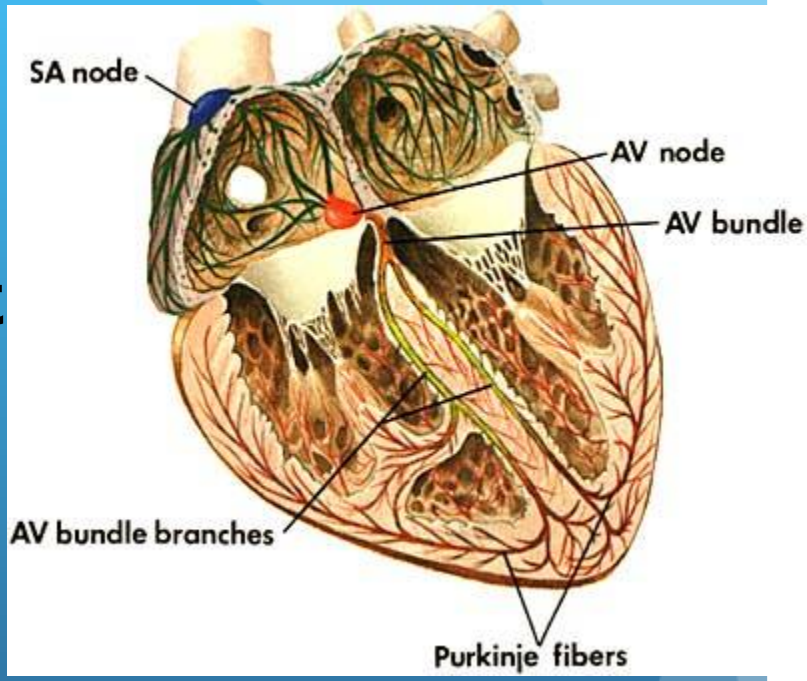
II. Heart Nervous Tissue

A. Heart contains NODAL TISSUE, which has characteristics of both nerve and muscle tissue to ensure rapid and coordinated heart contractions.

B. Sinoatrial (SA) Node
   1. Located in the upper back wall of the right atrium.

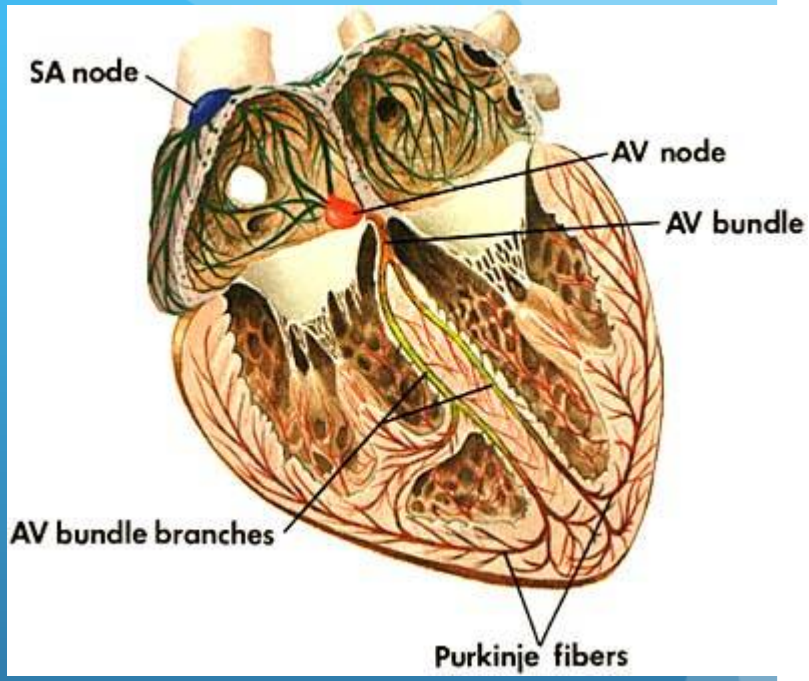


2. The SA node initiates the heartbeat by sending out a signal automatically about every 0.85 seconds to make the atria contract.
3. Called the "pacemaker" because it keeps the beat regular.
4. An implanted artificial pacemaker can send out an electric signal every 0.85 seconds to stabilize the heart rate if the SA node doesn't work.

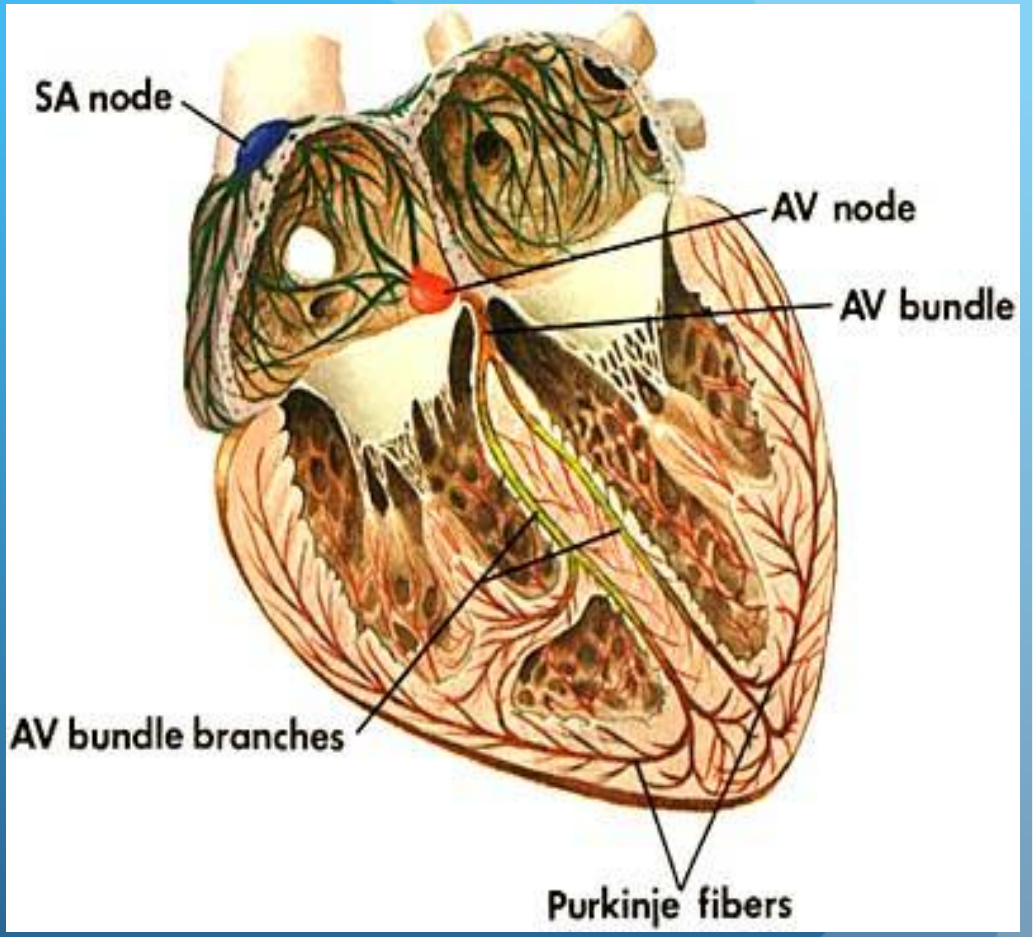


C. Atrioventricular (AV) Node

1. Located in the base of the right atrium near the septum.
2. Branches from the SA node are spread over the atria and also to the AV node.
3. When the pulse sent out by the SA node reaches the AV node, the AV node sends out a signal along special conducting fibers called AV bundle down the septum to the Purkinje fibres that spread through the ventricles.

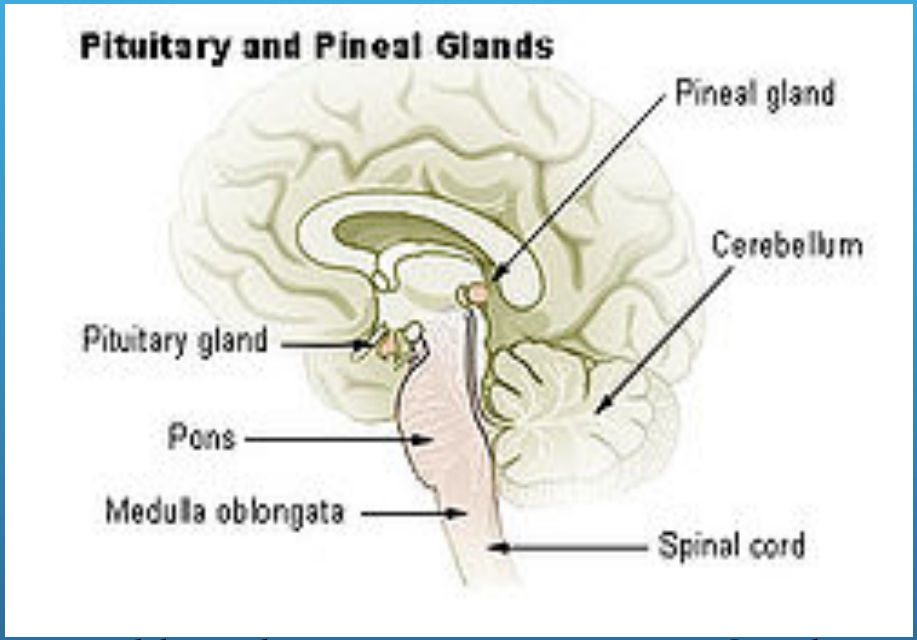


D. Purkinje fibers stimulate cardiac muscle at the base of the heart ventricles and moves up like a wave to cause the ventricles to contract.



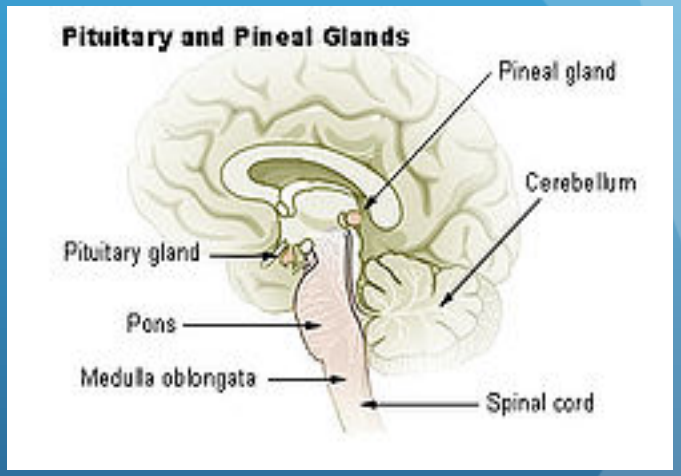
III. Control by the Brain

A. Nervous control controls the heart rate



B. Controlled in a part of the brain called the **MEDULLA OBLANGATA**

1. The medulla sends messages via the autonomic nervous system.
   a. Sympathetic nerve branches tells the heart to "SPEED UP!"
   b. Parasympathetic nerve branches tells the heart to "SLOW DOWN!"



2. Various factors, such as stress, oxygen levels, and blood pressure determine how the autonomic system will affect heart rate.

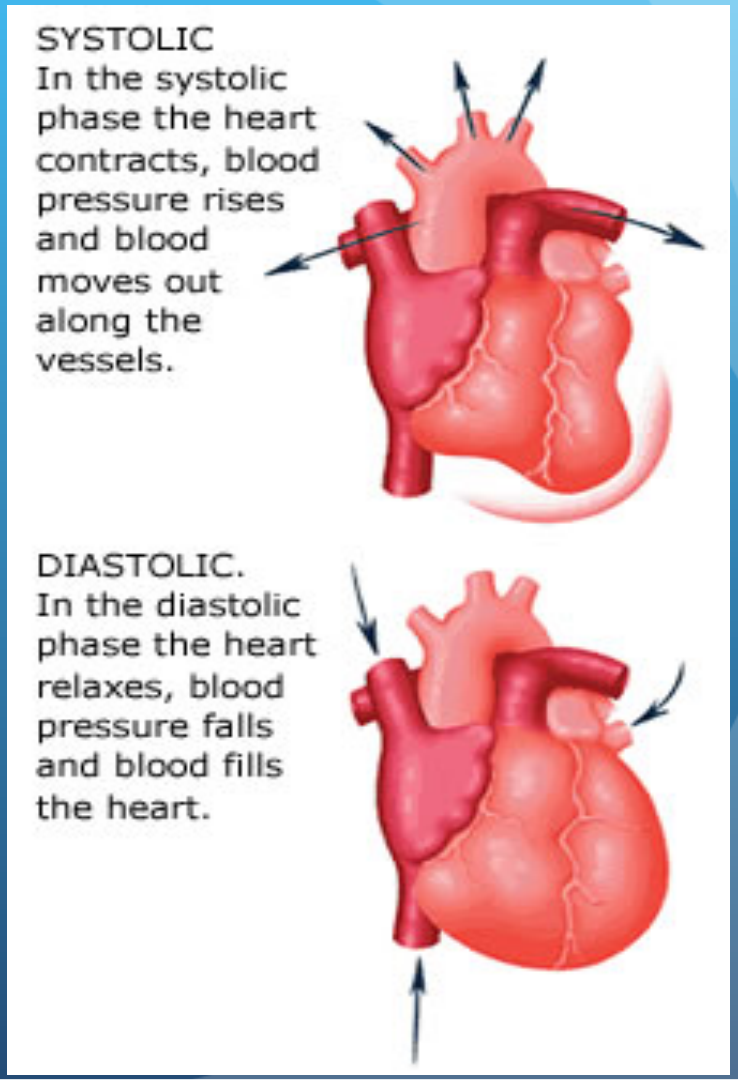
Systolic and Diastolic Pressures

I. Systole and Diastole

A. SYSTOLE = CONTRACTION of heart muscle.

B. DIASTOLE = RELAXATION of heart muscle.

TED-Ed Blood Pressure Animation



II. The Cardiac Cycle

A. Occurs about 70 times per minute.

B. Each heartbeat can be divided as follows:

Time (Duration)	Atria are in...	Ventricles are in...
0.15 SEC.	Systole	Diastole
0.30 SEC.	Diastole	Systole
0.40 SEC.	Diastole	Diastole

C. Each contraction will force 70 mL of blood to be circulated.

1. Results in a total blood volume pumped per minute of ≈ 5L.

2. Entire body's blood volume is circulated each minute.

D. PULSE is the alternate expanding and recoiling of an arterial wall that can be felt in any artery that runs near the surface of the body. Animation

1. Radial artery in wrist, carotid artery in neck are common places to check.

2. Pulse rate indicates the rate of heartbeat.

III. Blood Pressure

1. **Pressure of the blood against the wall of a blood vessel.**
2. **Created by the pumping action of the heart.**
3. **When the heart contracts, the blood is forced into the arteries under a great deal of pressure.**

IV. Measuring Blood Pressure

A. Measured by a **sphygmomanometer**.

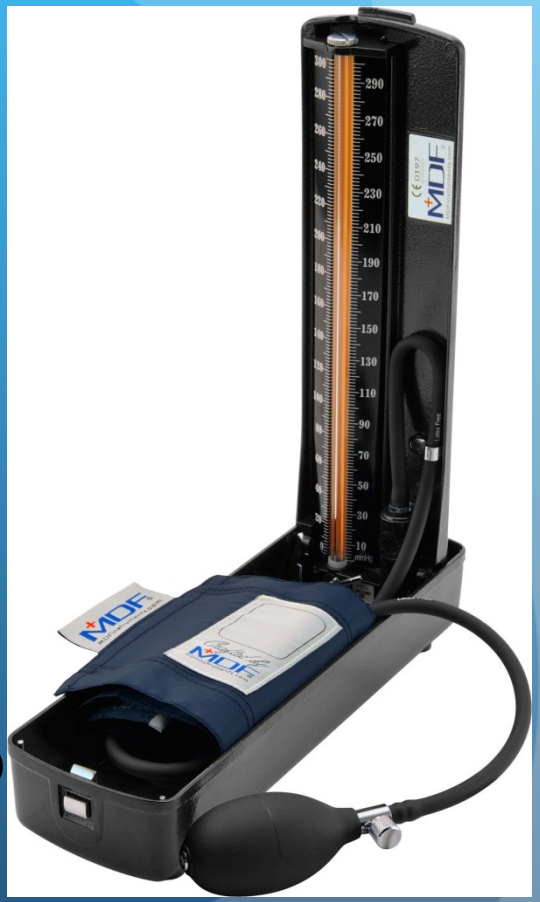
B. **SYSTOLIC BLOOD PRESSURE** is the **highest** arterial pressure reached during ejection of blood from the heart

C. DIASTOLIC BLOOD PRESSURE is the lowest arterial pressure when the ventricles are relaxing.

D. Blood pressure decreases with distance from left ventricle.

E. Normal resting blood pressure is 120 mm Hg over 80 mm Hg in brachial artery of arm.

1. 120 mm Hg is how high a column of mercury would be pushed as soon as the ventricles contract.
2. As the ventricles relax, pressure decreases down to 80 mm Hg.
3. It would continue to decrease except that at this time the ventricles fill up and contract again pushing the pressure up to 120 mm Hg (again).



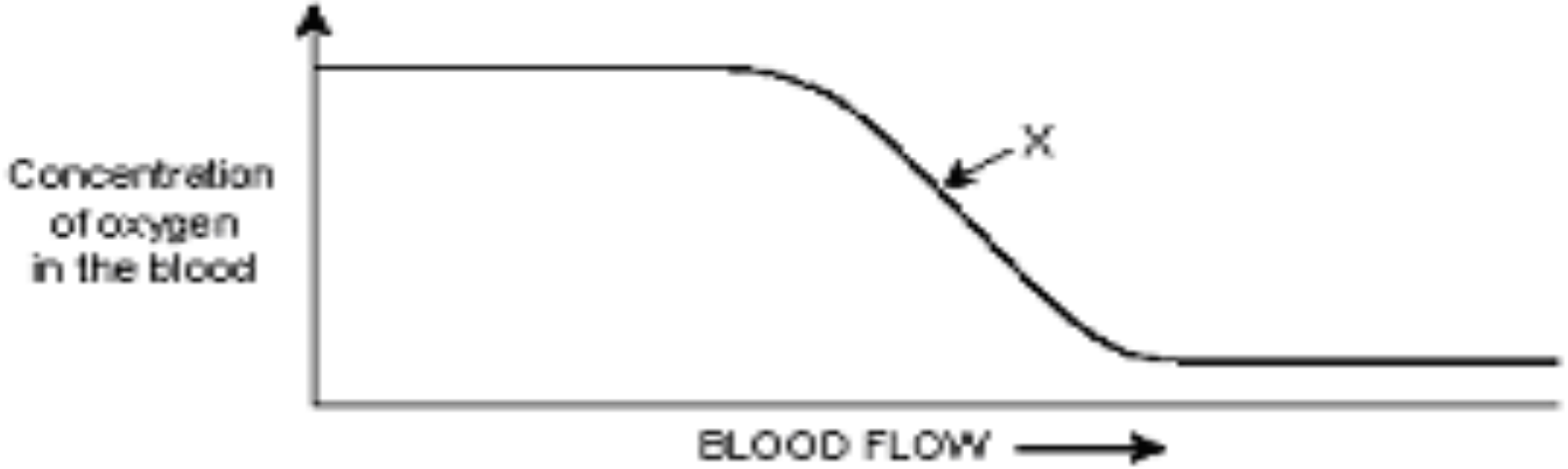
4. The drop in pressure from 120 mm Hg to 80 mm Hg is due to:

   a. Elastic nature of the arteries.
   b. Blood being distributed throughout the body.
   c. Blood pressure drops as the blood is distributed to a "low" of about 10 mm Hg in the capillaries.

F. By the time the blood reaches the venules and veins it does not have enough pressure to reach the heart on its own.

1. Minute contractions of the skeletal muscle will push the blood back to the heart.
2. Valves prevent backward flow.

TED-ED 231/2 Hours



Transport Fluids

I. Body Fluids

A. Human beings are approximately 70% water by body weight.

B. Most of the water is within cells.

C. A smaller amount of water is found within:

1. Tissue fluid (surrounds cells)
2. Lymph vessels
3. Blood vessels

II. Blood

A. BLOOD is a liquid connective tissue.

B. Average person has about 5 to 6 liters of blood.

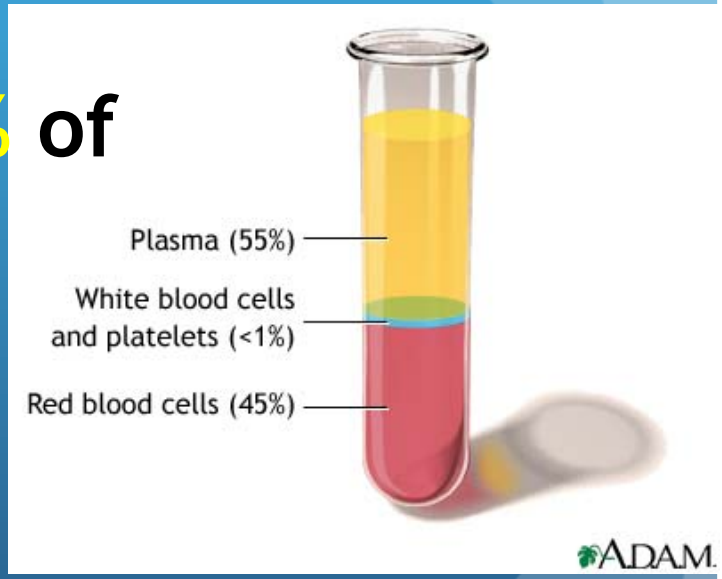
C. Blood is required by the body to maintain homeostasis.

D. Blood functions in
   1. Transport of gases, wastes, and nutrients
   2. Clotting to seal injuries
   3. Infection fighting

III. Two Main Components of Blood

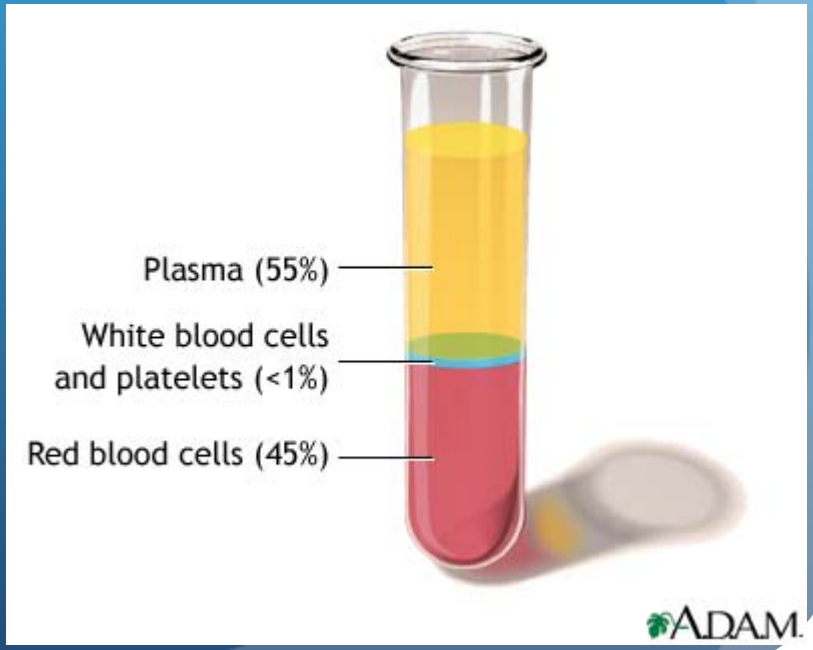
A. PLASMA (the liquid portion of blood)

1. Makes up about 55% of blood volume.
2. Contains water.
3. Contains organic and inorganic substances (proteins, gases, salts, nutrients, wastes).



B. FORMED ELEMENTS (the solid part of blood)

1. Makes up about 45% of blood volume.
2. About 30 trillion blood cells in an adult.



3. Each cubic millimeter of blood contains 2 main types of formed elements
   A. Red blood cells (RBC)
      i. 4 - 6 million per mL of blood

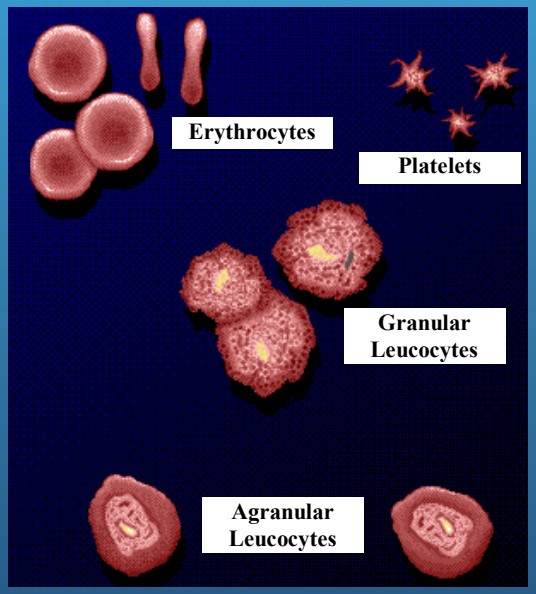
      ii. More RBC/mL in males than females

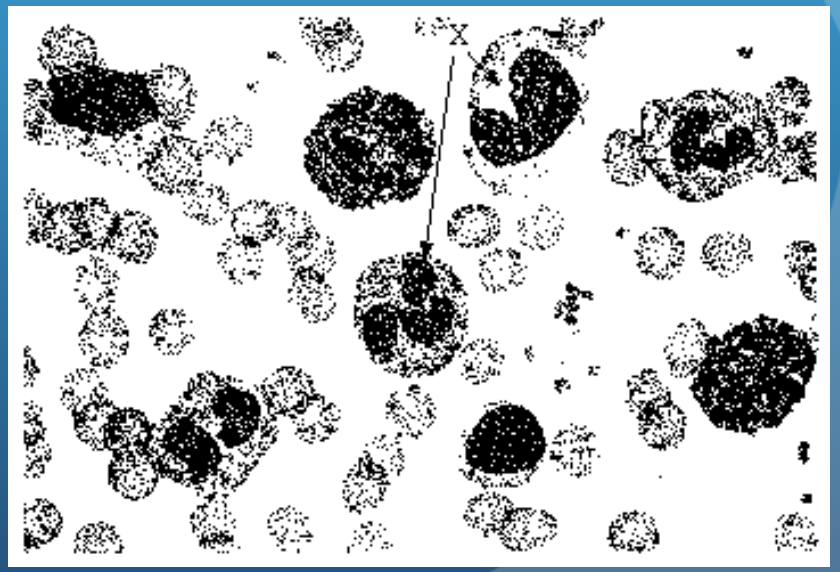
      iii. Number in blood cells is related to O_2 concentration in air
      ex. People who live at high altitudes have more RBC

      iv. Increasing the number of RBC/mL can aid athletic performance ("blood doping")

b. White blood cells

i. Average total of 7,500 per mL of blood





Plasma Components

Plasma Constituent	Function	Source
Water	Maintains blood volume and transports molecules	Absorbed from large intestine
Plasma Proteins: a. Albumin	All maintain blood osmotic pressure & buffer pH Transport	Liver
b. Fibrinogen	Clotting	Liver
c. Globulins	Fight Infection	Lymphocytes
Gases: a. Oxygen b. CO_2	 Cellular Respiration End product of metabolism	 Lungs Tissues
Nutrients: Fats, glucose, amino acids, nucleotides, etc.	Food for cells	Absorbed from intestinal villi

Salts: Na^+, K^+, Cl^-, $NaHCO_3$, etc.	Maintain blood osmotic pressure/pH, aid metabolism	Absorbed from intestinal villi
Wastes: (urea, ammonia)	End products of metabolism	Tissues
Vitamins	Cofactors for enzymes	Absorbed from intestinal villi
Hormones, (Thyroxin, adrenalin, estrogen etc.)	Varied	Varied Glands

Blood Proteins

A. Are required for the transport of many molecules.

B. For example, cholesterol is a lipid that is insoluble in plasma so it must be carried by proteins.

C. Blood proteins also contribute to the viscosity of blood which aids in transport.

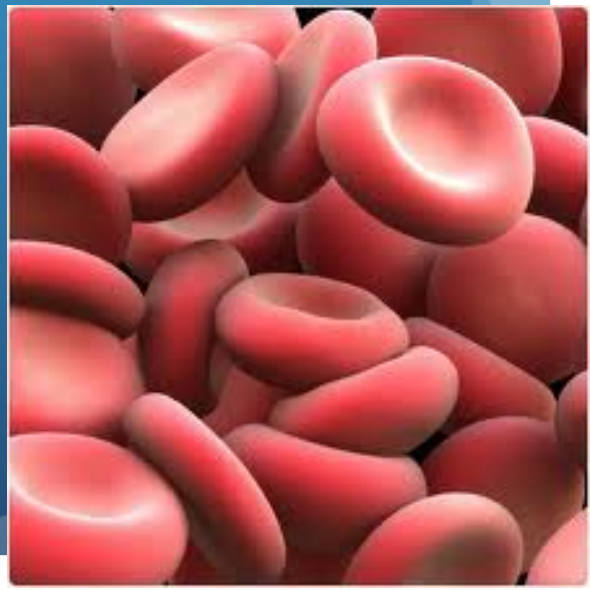
D. Blood proteins also contribute to osmotic pressure, which maintains blood volume.

J9. Blood Cells

I. Red Blood Cells (Erythrocytes)

A. Red blood cells (RBC) are small, biconcave, disk-shaped cells without nuclei.

B. Makes up over 95% of the formed elements.



C. Transport O_2, hydrogen ions and some CO_2
D. RBC are made by cells called STEM CELLS in red bone marrow
   1. Over 2 million produced per second!
   2. Made in the skull, ribs, vertebrae, and ends of the long bones.
   3. Stem cells continuously divide.
      a. Pass through several developmental stages during which they lose a nucleus, gain hemoglobin and gets much smaller.

4. Oxygen levels in blood determine the rate of RBC formation.

   a. When oxygen tension is low, the kidneys produce a chemical called renal erythropoietic factor (REF) that, after combining with globulin from the liver, causes the bone marrow to produce more RBC.

5. RBC live for only 120 days.

   a. RBC are destroyed in the liver and spleen.

   b. Iron is recovered from the hemoglobin and sent to the bones, while the heme portion is chemically degraded and is excreted by the liver in the bile as bile pigments.

II. White Blood Cells (Leukocytes)

A. White blood cells (WBC) are usually larger than RBC (8 - 20 m), have a nucleus, and appear white (stained blue).

B. There is 1 WBC for every 600 RBC.

ANIMATION

C. WBC fight infections ANIMATION 2

1. Primarily dependent on neutrophils and lymphocytes.
2. Red bone marrow continually produces WBC, except lymphocytes and monocytes, and keeps a reserve ready.
3. Lymphocytes and monocytes are produced by lymphatic tissue located in the lymph nodes and spleen.
4. When a parasite or virus invades, the reserves of WBC are released and more are manufactured.
5. Fever is caused by the increased production of WBC.
6. WBC are very specific for various illnesses so their count can help doctors diagnose patients.
   a. E.g. mononucleosis characterized by greater numbers of dark staining lymphocytes.

D. There are two main types of WBC

1. Granulocytes - have granules in the cytoplasm and a many-lobed nucleus joined by nuclear threads (called "polymorphonuclear").

a. Neutrophils
   i. 55 - 70% of WBC.
   ii. Phagocytize primarily bacteria.
   iii. The granules are lysosomes.

Fig. 8 - Neutrophil

b. Eosinophils
   i. 1 - 4% of WBC.
   ii. Phagocytizes and destroys antigen-antibody complexes.
   iii. Involved in inflammatory and allergic responses.

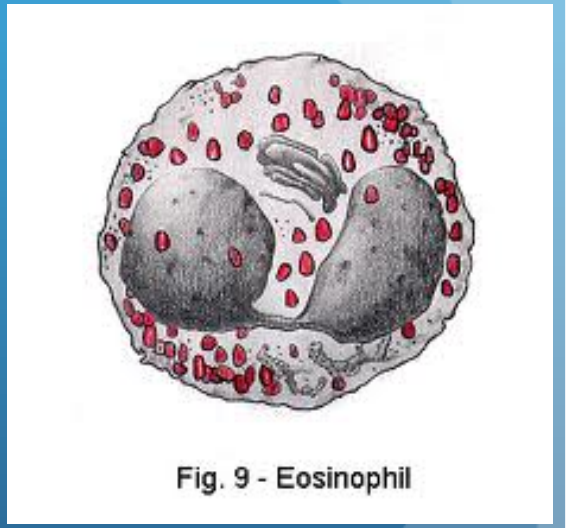


Fig. 9 - Eosinophil

c. Basophils
   i. 0.5 - 1% of WBC.
   ii. Involved in inflammatory and allergic responses.
   iii. Congregates in tissues, releases histamine when stimulated.

Leukocytes

white blood cells ~ WBC

agranular

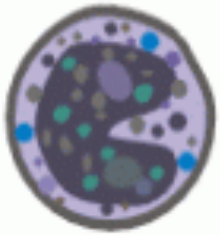
lymphocytes
20 - 25 %

T-cell, B-cell, NK Cell

monocytes
3 - 8%

granular

basophils
.5 - 1%



neutrophils
60 - 70%

eosinophils
2 - 4%

2. Agranulocytes: Do not have granules, and have a circular (lymphocytes) or indented (monocytes) nucleus.

a. Lymphocytes
   i. 20 - 30% of WBC.
   ii. Are the smallest white blood cells.
   iii. Different types: T and B cells
      1. Type T lymphocytes kill virus-containing cells.
      2. Type B lymphocytes produce antibodies in blood and lymph.

iv. Secrete a protein called IMMUNOGLOBULINS.

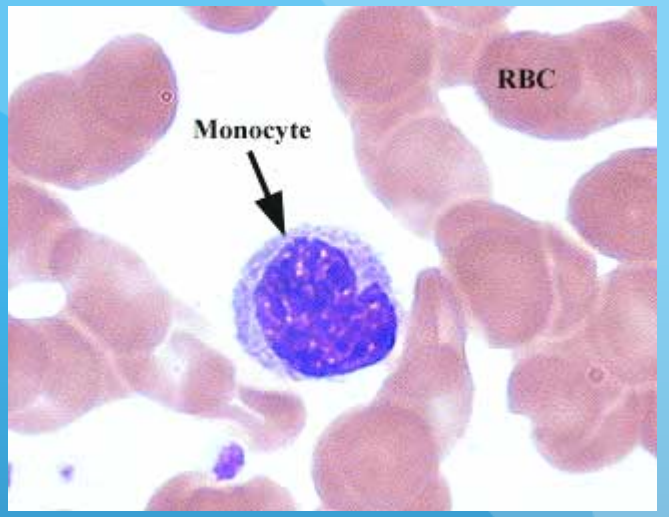
1. Antibodies combine with foreign substances to inactivate them

2. When microbes invade the body, lymphocytes begin to multiply and they become transformed plasma cells.

3. Each microbe stimulates only one type of lymphocyte to multiply and form one type of plasma cell.

4. The type of plasma cell formed is the type that can make a specific antibody to destroy the particular microbe that has invaded the body.

b. Monocytes



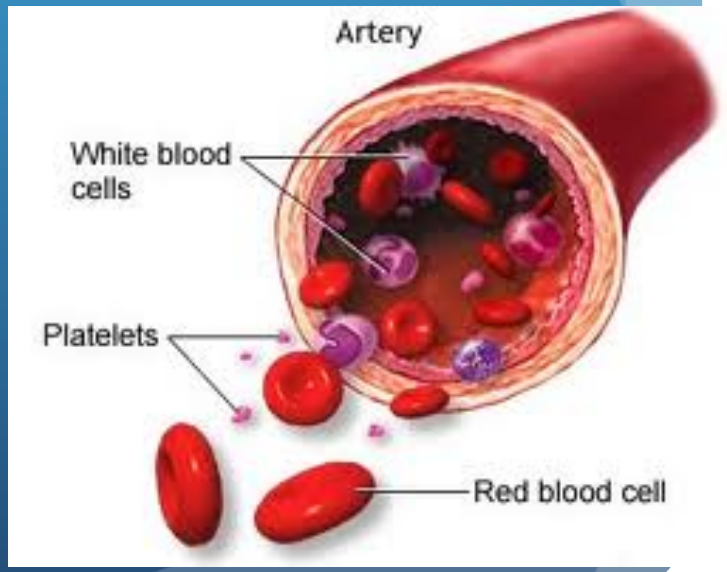
i. 2 - 8% of WBC.
ii. Become macrophages.
iii. Enlarge greatly in size at infections

III. Platelets (Thromobocytes)

A. From fragmentation of large cells called megakaryocytes in red bone marrow.

B. Produces 200,000,000,000 per day!

C. Function in blood clotting



IV. Hemoglobin (Hb)

A. Made of 4 amino acid chains (2 alpha () and 2 beta ()).

B. Each chain has iron-containing heme group which attaches to oxygen.

C. Hemoglobin is an excellent carrier of oxygen because it weakly binds with oxygen in the cool, neutral conditions in the lungs, and easily gives O_2 up in the warmer and more acidic tissues.

D. Hemoglobin is a red pigment so red blood cells appear red.

1. Colour can change based on what the hemoglobin is attached to.
    a. Oxyhemoglobin (HbO_2)
        i. Hemoglobin bound to oxygen
        ii. Bright red
    b. Reduced hemoglobin
        i. Hemoglobin that has lost its oxygen
        ii. Dark purple

E. Carbon monoxide (CO) is a poison found in car exhaust.

1. It binds to Hb better than oxygen, and stays bound for several hours regardless of the environmental conditions.

2. CO poisoning can lead to death.

V. Infection Fighting In a Nutshell Video

A. Body's first line of defense against invading pathogens like bacteria and viruses is the skin

B. Second line of defense is the blood
   1. White blood cells

   2. Gamma globulins

VI. The Inflammatory Reaction

A. Whenever the skin is broken due to a minor injury, a series of events occur that are known as the inflammatory response because there is swelling and reddening at the site of the injury.

B. This response is designed to get the body's defenses marshaled as quickly as possible at the site where they are needed.

C. When blood vessels and tissue cells get ruptured by an injury, they release precursors of BRADYKININ

1. A chemical with several jobs

2. Bradykinin initiates nerve impulses that signals PAIN

3. Bradykinin causes MAST CELLS (a type of cell that resides in tissues that is derived from Basophils) to release histamine, which together with bradykinin causes a capillary to become enlarged and more permeable.

D. Enlarged capillary causes the skin to redden and its increased permeability allows proteins and fluids to escape so that swelling results.
E. Meanwhile, bacteria and viruses are also entering through the rupture.
F. Lymphocytes release antibodies that attack the invading pathogens, preparing them for phagocytosis by neutrophils or monocytes.
G. Once monocytes have arrived on the scene, they swell up to five to ten times their original size and become macrophages (large phagocytic cells that are able to devour a hundred invaders and still survive).
H. Dead neutrophils plus cells, bacteria, and WBC form pus, a thick yellowish fluid.

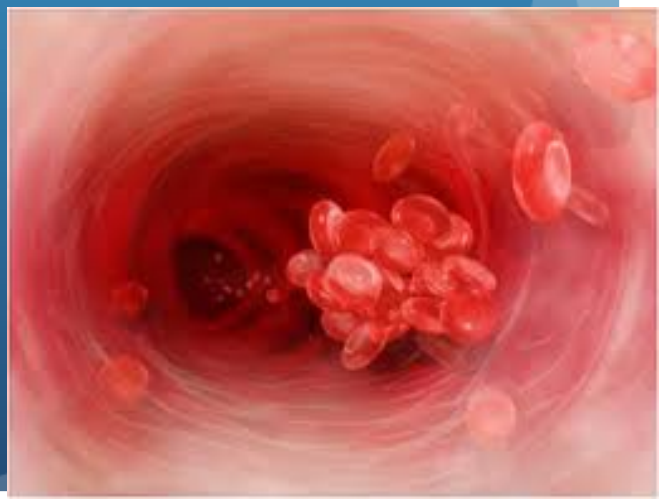
VII. Blood Clotting Ted-Ed Wounds

A. After an injury, coagulation or "clotting" takes place to prevent excessive blood loss.

B. Requires the action of platelets, prothrombin and fibrinogen.

C. Prothrombin and fibrinogen are manufactured and deposited in the blood by the liver.

D. Vitamin K is required for the production of prothrombin.



E. A simplified summary of the steps involved in clot formation:

1. Platelets clump at the site of the puncture and partially seal the leak.

2. Platelets and injured tissues release the enzyme prothrombin activator that activates prothrombin to thrombin. Calcium ions (Ca^{2+}) are necessary for this step.

3. Thrombin acts as an enzyme and severs two short amino acid chains from each fibrinogen molecule.

4. These activated chains join end to end to form long ends of fibrin.

5. Fibrin threads entangle red cells and platelets in the damaged area and form the framework of the clot.
6. Red cells trapped in the clot give it its red colour.
7. Clotting takes place faster at warmer temperatures than cold because it is controlled by enzymes.
8. Serum is plasma from which the fibrinogen has been removed due to clotting.
9. A fibrin clot is only a temporary repair and eventually, an enzyme called plasmin destroys the fibrin network and restores the fluidity of plasma.

1.ANTIGENS and ANTIBODIES

I. Antigens

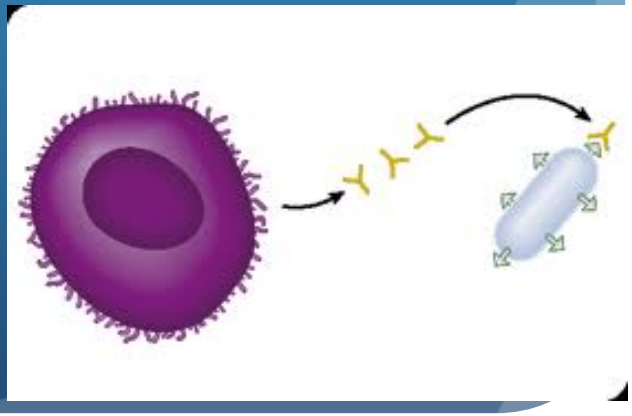
A. A foreign substance (usually a protein, sometimes a carbohydrate) that stimulates the release of antibodies to it.

B. Usually organic and usually small enough to enter via the respiratory, circulatory or digestive system

B. E.g. Protein coat of a viruses, bacteria, the cells of transplanted organs, etc.

C. If the immune response is overly sensitive, responding to small organic materials that do not, in themselves, usually cause disease (e.g. pollen grains, food molecules)

person has ALLERGIES to such materials



II. Antibodies

ANIMATION

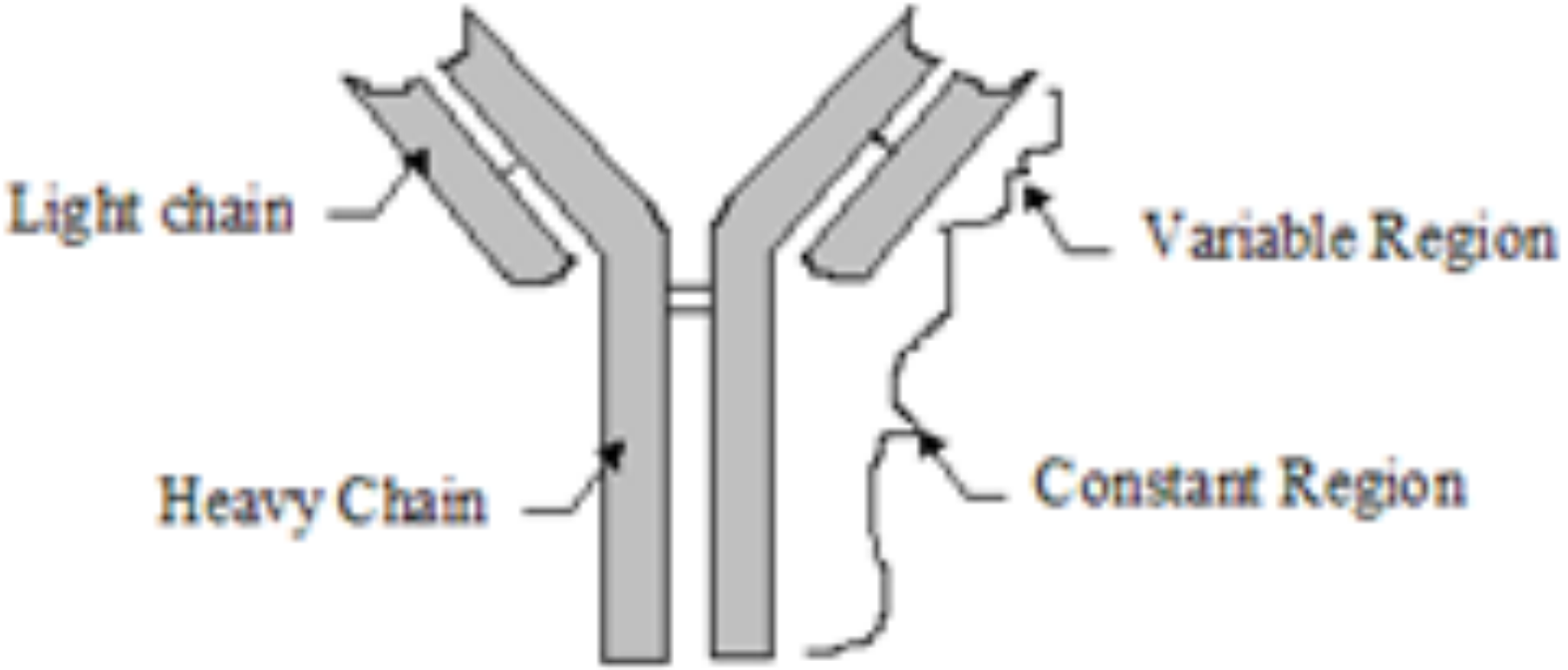
A. Very specific proteins that attach to invading pathogens.

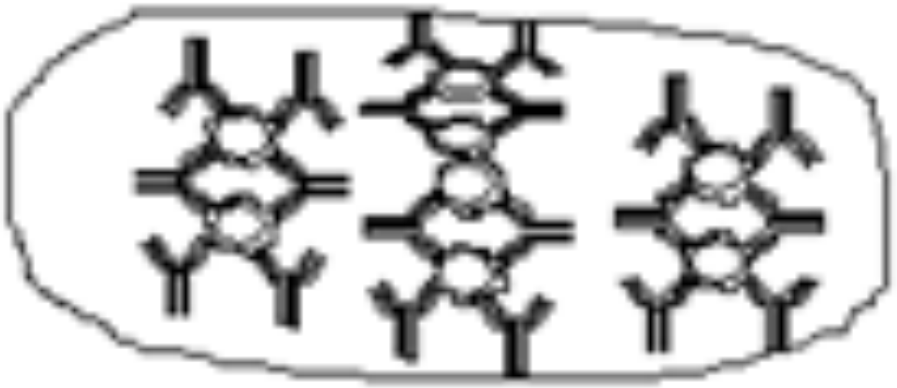
B. Lymphocytes produce antibodies in response to invading pathogens

C. Each lymphocyte produces one type of antibody that is specific for one type of antigen.

D. Antibodies combine with antigens in such a way that the antigens are rendered harmless.

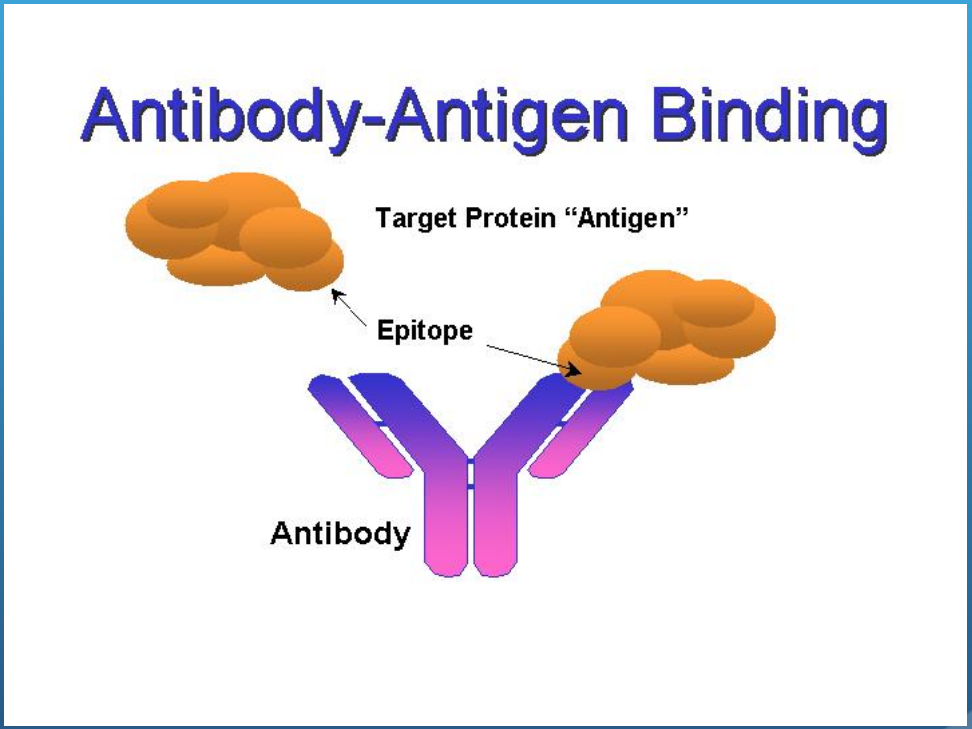
STRUCTURE OF AN ANTIBODY





Antibodies binding to antigens (proteins on surface of a cell)

E. Each antibody fits its antigen like a lock and key.



F. Are immune if a person has antibodies for a particular antigen.

G. The blood contains lymphocytes that can remain in the system for years, ready to produce antibodies if that antigen is detected.

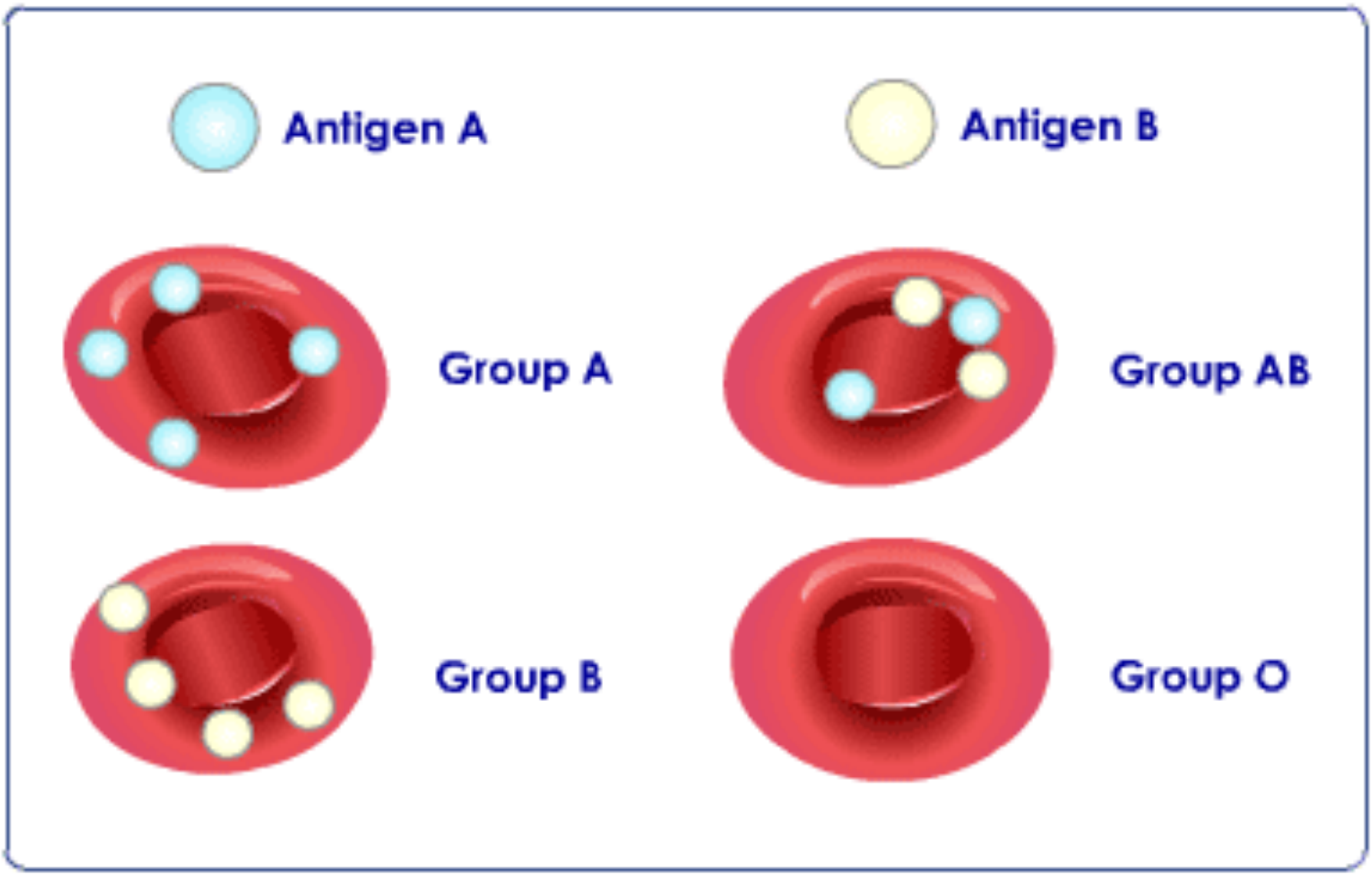
H. Exposure to the antigen, either naturally or by way of a vaccine, can cause active immunity to develop.

1. BLOOD TYPING

I. ABO Blood Types TED-ED Blood Types

A. Human blood is classified according to the antigens present on the surface of the red blood cells.

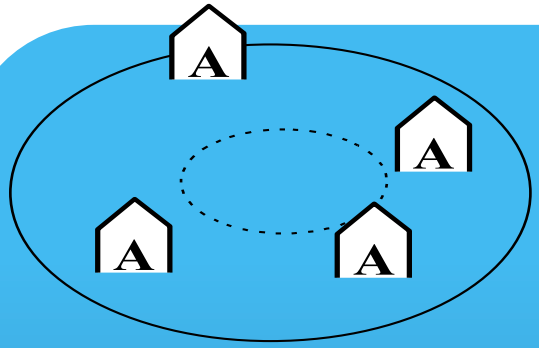
B. Two antigens called "A" and "B" may be present on the red blood cells


Antigen A
Antigen B
Group A
Group AB
Group B
Group O

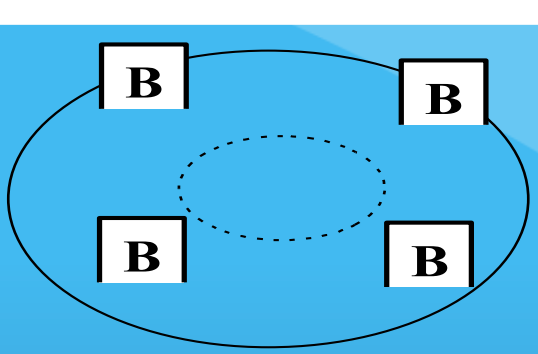
C. **Each individual also carries antibodies in his/her plasma to the antigens not present on that individual's red cells.**

D. **Group ABO Type Summary**

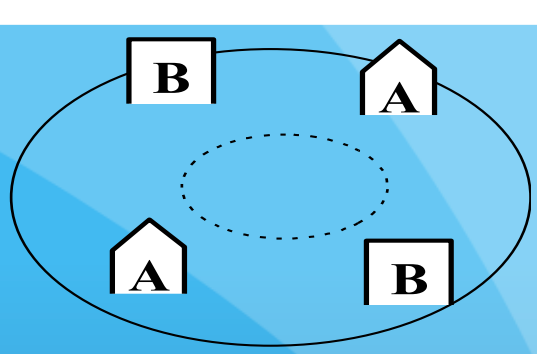
Type	Antigen	Antibody
A	A	b
B	B	a
AB	A,B	none
O	none	a,b



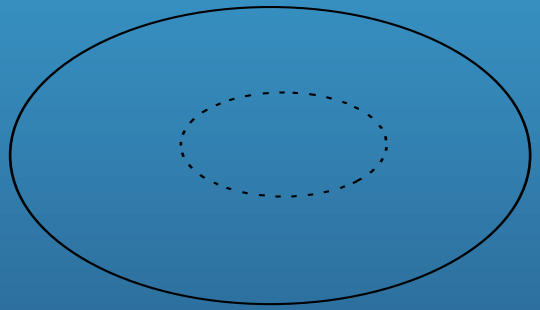
TYPE "A" BLOOD
- has type "A" **antigens**
- makes type b **antibodies** (antibodies that attack B antigens)



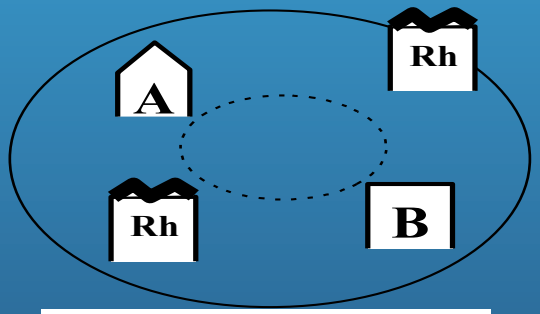
TYPE "B" BLOOD
- has type "B" **antigens**
- makes type a **antibodies** (antibodies that attack A antigens)



TYPE "AB" BLOOD
- has both "A" & "B" **antigens**
- makes **NO ANTIBODIES** to A or B antigens.



TYPE "O" BLOOD
- has **neither** A nor B **antigens**
- makes both type a and type b **antibodies**



Rhesus Antigen (Rh factor)
- Rh factor is **another antigen** that can be present on RBC.
- Either you have it ("+") or you don't ("-")
- If you are Rh negative, you **don't make antibodies** to Rh unless you have been exposed to it.
- The person above is **Rh^+**

II. Rh System

A. Rh factor is another antigen found on RBC.

B. People with this Rh antigen on the RBC are Rh positive.

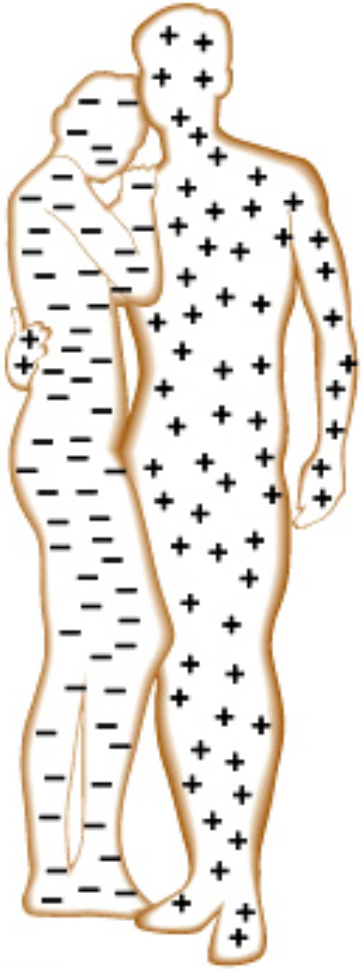
C. People without this Rh antigen on the RBC are Rh negative.

D. Rh negative individuals do not normally make antibodies to the Rh factor, but they will make them when exposed to the Rh factor.

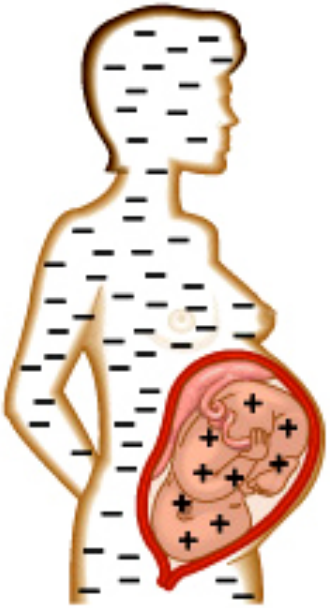
E. It is possible to extract these antibodies and use them for blood type testing, since Rh positive blood will agglutinate when mixed with Rh antibodies.

F. The Rh factor is very important during pregnancy.

1. If the mother is Rh negative and the father is Rh positive, the child may be Rh positive.
2. During gestation, it is normal that a few red cells from the child will find their way into the mother's system
3. If the mother becomes pregnant with another Rh positive baby, Rh antibodies may cross the placenta and destroy the child's red cells → fetal erythroblastosis.



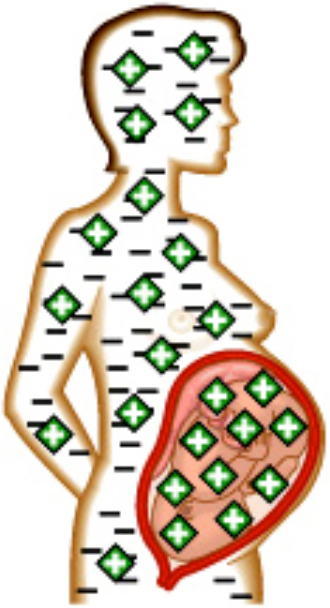
Rh-negative woman and Rh-positive man conceive a child



Rh-negative woman with Rh-positive fetus

Cells from Rh-positive fetus enter woman's bloodstream

Woman becomes sensitized—antibodies (◈) form to fight Rh-positive blood cells



In the next Rh-positive pregnancy, maternal antibodies attack fetal red blood cells

- Can give Rh^- women an Rh immune globulin injection called RhoGAM just after the birth of any Rh^+ child. This injection will destroy any red cells left over from the baby, before the mother has a chance to start producing her own antibodies.

- Game

III. Blood Transfusions

A. Blood recipients may only receive donated blood for which they have no antibodies in their plasma.

B. If the same antigen and antibody are present, agglutination (or clumping) of red cells will occur and can cause death.

C. AB^+ people are universal acceptors because they can receive any blood type in transfusion and not react.

D. O^- people are universal donors because their RBCs can be given to anyone, since they do not have any antigens on their surface to trigger an immune response