Cardiovascular System

Chapter 32

BIOL 1000

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Introduction

- The major transportation fluid in the body.
- 8% of the total body fluids.

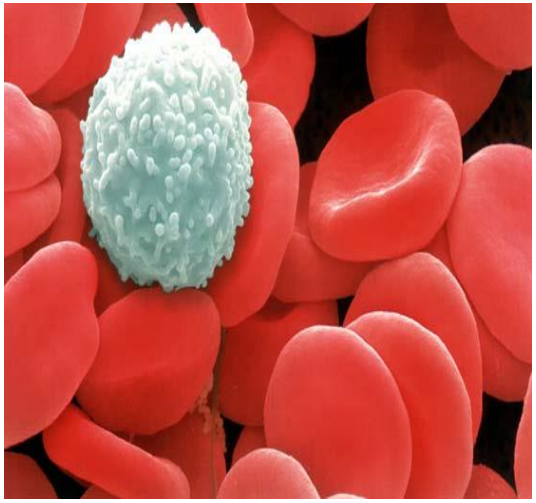
Roles of the Cardiovascular system:

1- Transport of substances (O_2, CO_2, nutrients, and hormones)

2- Regulation of body temperature

3- Defense against blood loss, microbes and toxins

Some organisms do not have a circulatory system such as single celled organisms, sea anenomes, jelly fish, and flatworms (tapeworms and planaria)



Circulatory System

- Consists of a pumping heart and blood vessels
- Two types of circulatory fluids:
  - Blood OR
  - Hemolymph

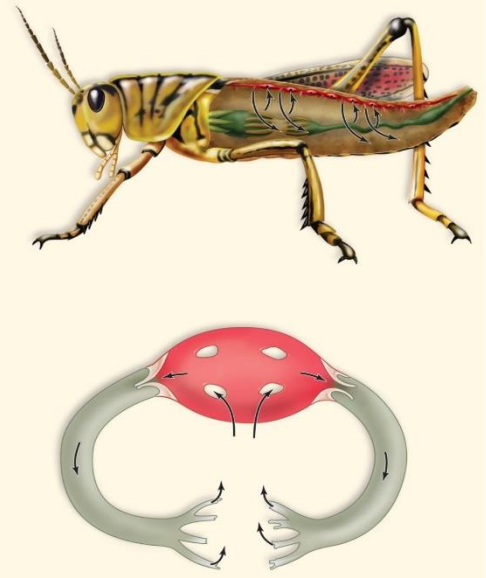
Transport

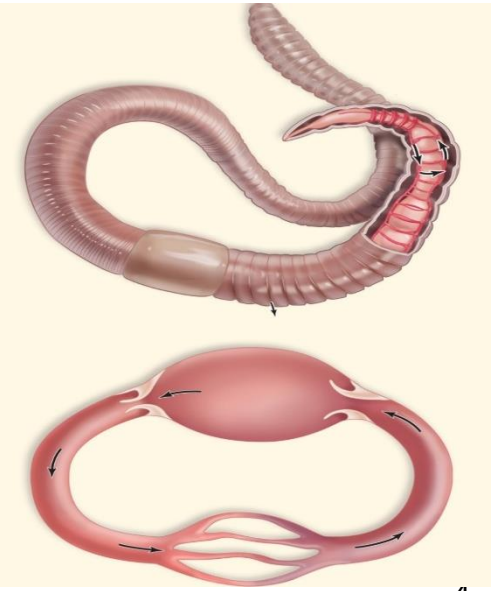
Open Circulatory System:

- Heart pumps hemolymph via vessels.
- Vessels empty into tissue spaces

Closed Circulatory System:

- Heart pumps blood to capillaries
- Gases and materials diffuse to and from nearby cells
- Vessels return blood to heart without contact between blood and tissues

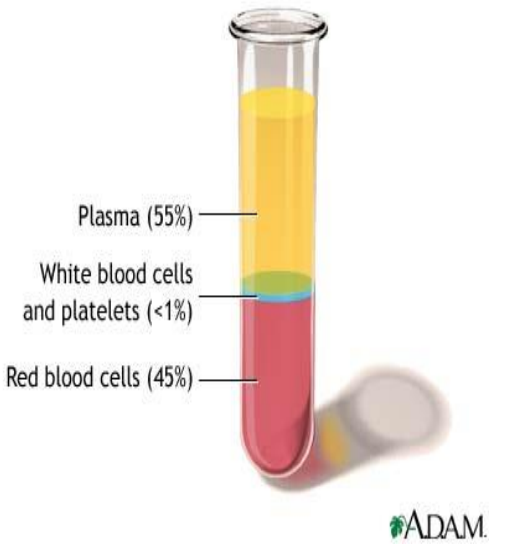




Blood Composition

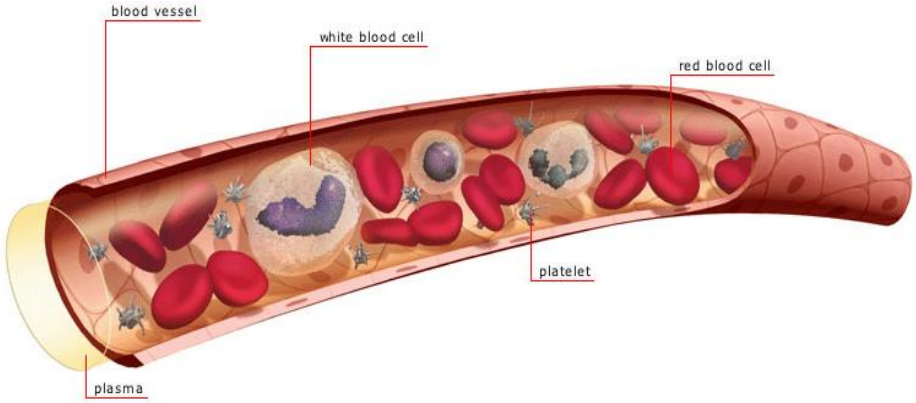
Plasma:

- The fluid portion.
- 55% of blood volume.
- Made up of water (90%), many ions, nutrients, gases, and proteins.



Formed elements:

- The cellular portion
- 45% of total volume
- Made up of: 1- Red blood cells (Erythrocytes), 2- White blood cells (Leukocytes), and 3- Platelets (Thrombocytes).



RBCs

Red blood cells also called erythrocytes:

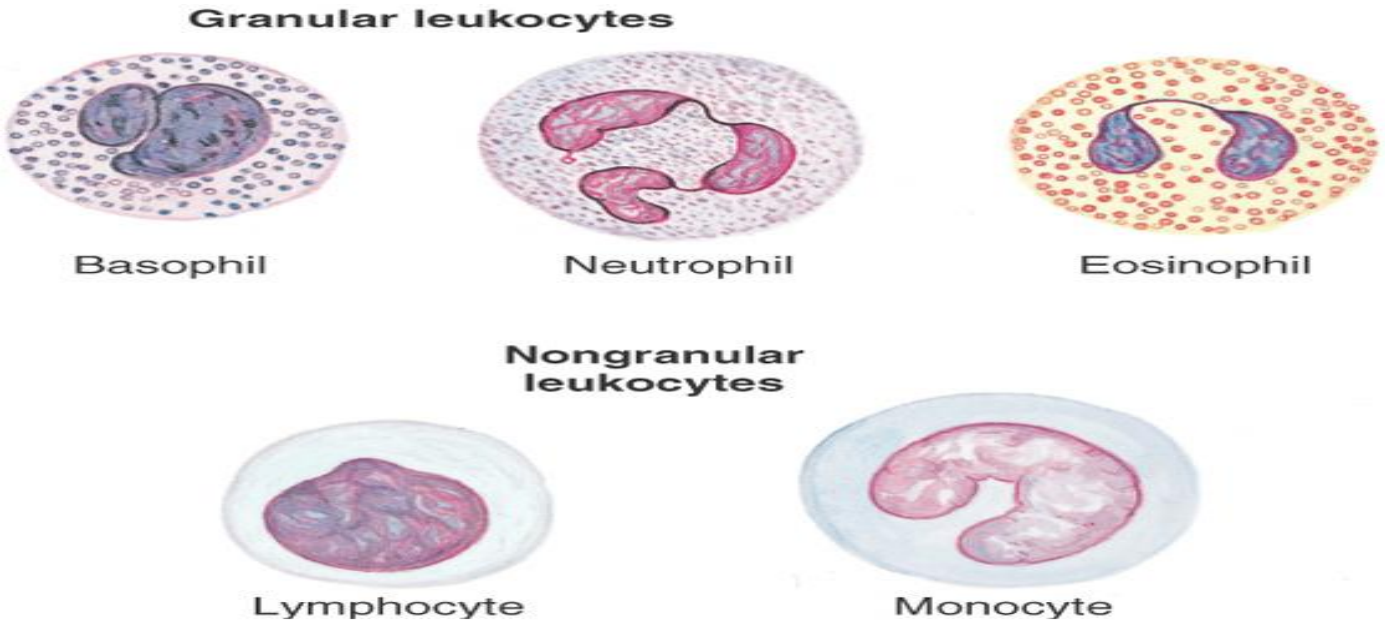
- They are the most numerous among formed elements.
- They are anucleated cells
- Their lifespan is 120 days
- Transport Oxygen
- Present antigen on the surface to determine blood type

White Blood Cells

- Also called leukocytes. Contain a nucleus and lack hemoglobin
- Important in defense .
- Classification depends on the presence or absence of granules and the staining characteristics of their cytoplasm.

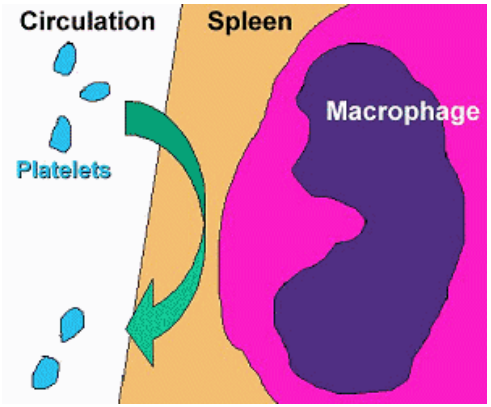
1- Granulocytes: Neutrophils, Eosinophils, and Basophils.

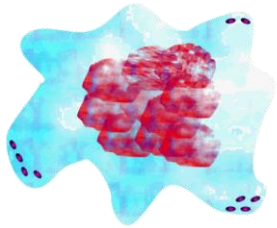
2- Agranulocytes: Lymphocytes, and Monocytes



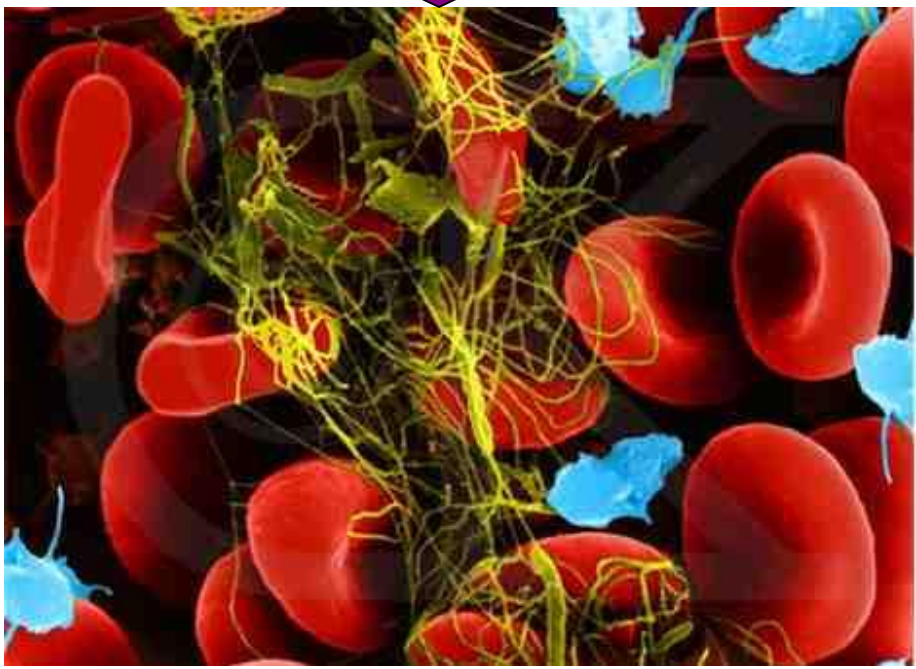
Platelets

- These are anucleated disc-shaped cell fragments
- Function in blood clotting
- Life span 5-9 days, removed by macrophages in the liver and spleen.
- Blood clot consists of:
  - Platelets
  - Red blood cells
  - All entangled within fibrin threads





Blood clot formation



Blood Types: The ABO system

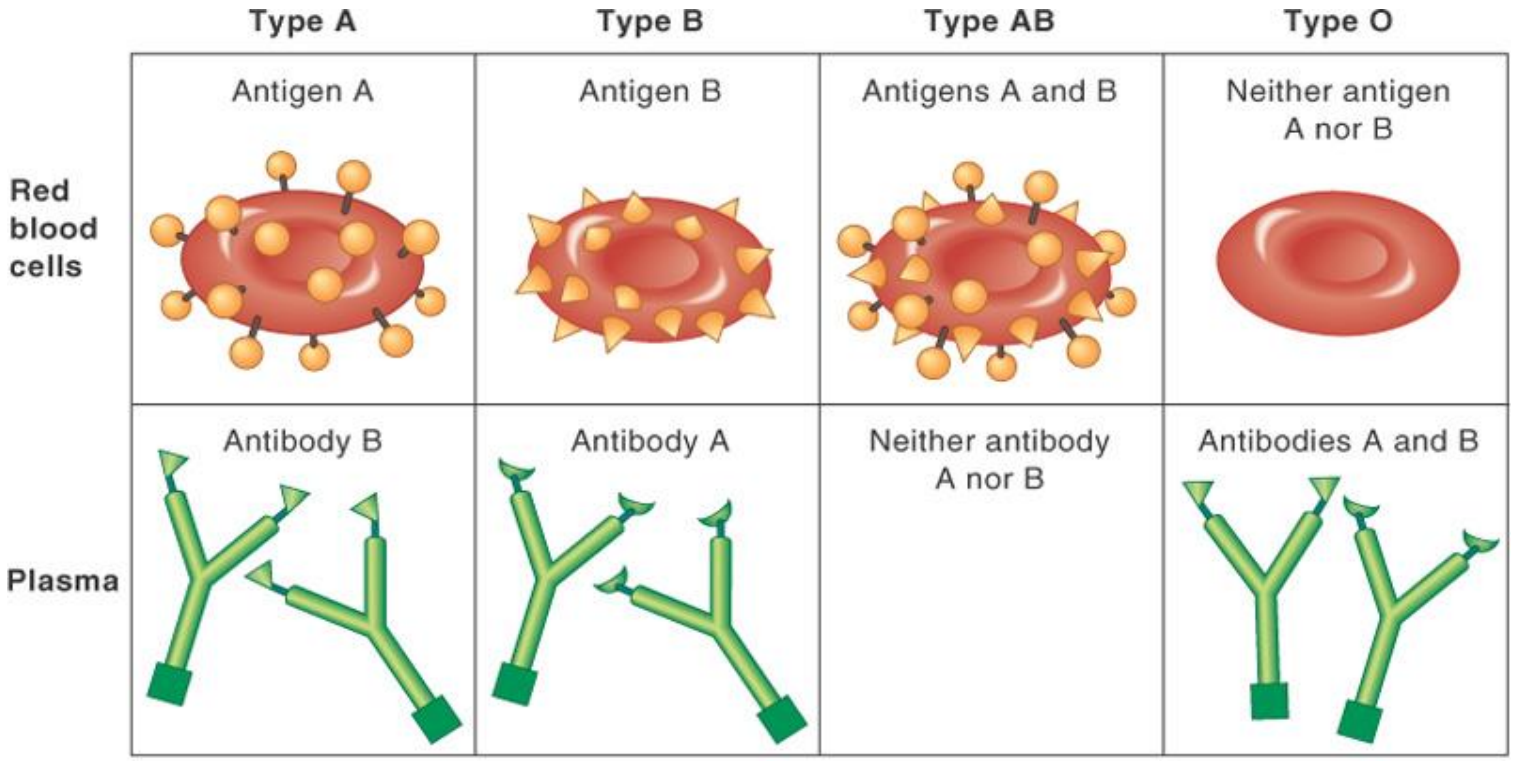
Every person's blood belongs to one of the four ABO blood groups

Blood types are named according to the antigens present on RBC surfaces.

Together with Rh system, they are the most important blood antigens to be taken into account during blood transfusion.

The ABO Blood types

Type A → antigen A on RBC surfaces, and antibody B in plasma
Type B → antigen B on RBC surfaces, and antibody A in plasma
Type AB → both A and B antigens on RBC surfaces, and no antibodies in plasma
Type O → No antigens on surfaces, and both antibodies A and B are in plasma

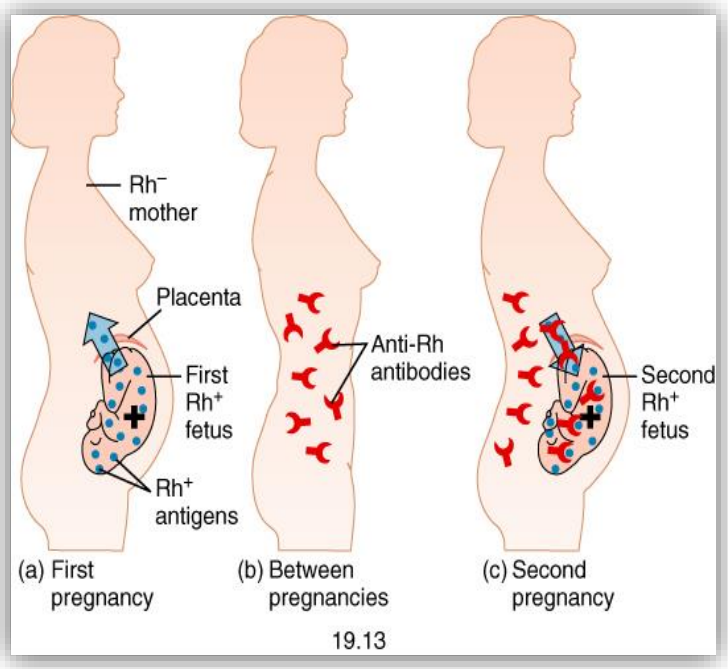


The Rh System

This is what determine if somebody is positive or negative.

Positive means antigen Rh is present on the surface, and negative means its absence

All Rh-negative mothers who carry an Rh-positive baby should be treated with a protein marketed as RhoGAM which stops anti-Rh antibodies production by the mother.

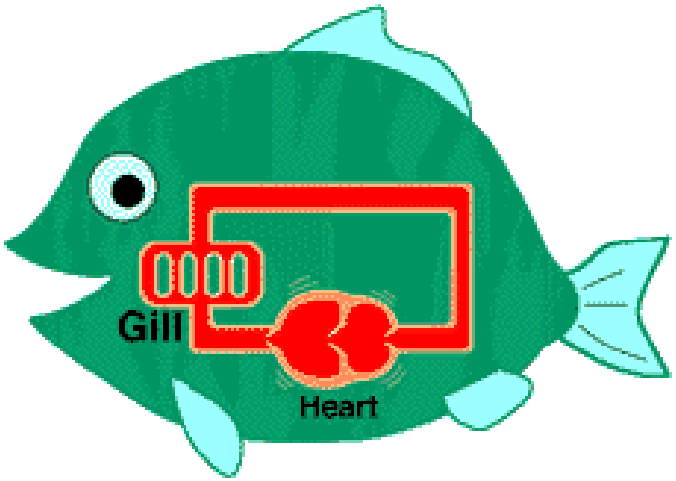


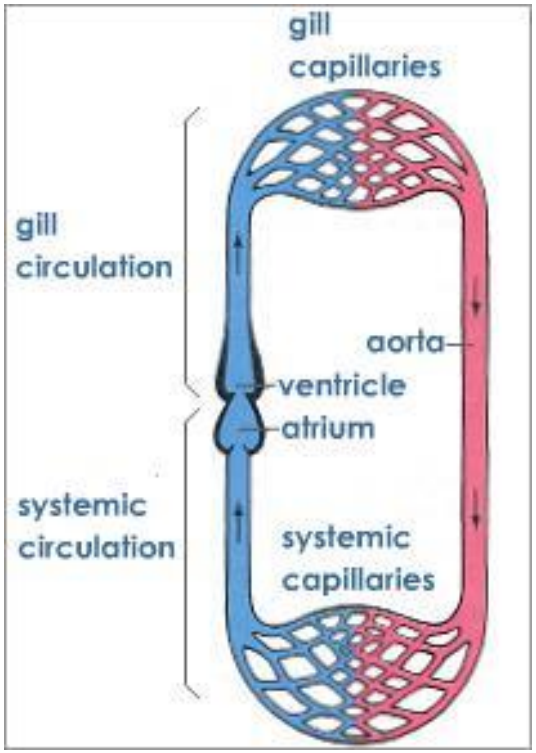
Transport in Vertebrates

- All vertebrates have a closed circulatory system called a **cardiovascular system**
- Vertebrate heart: 1- Atrium, 2- Ventricle
- Vertebrate vessels: **Arteries → Arterioles → Capillaries → Venules → Veins**.
- Single loop system: 2 chambers
- Double loop system: 3 or 4 chambers

Comparison of Circulatory Pathways

- Single loop-
  - Single atrium and single ventricle
  - Ventricle --> Gills --> Body --> Atrium
  - Disadvantage: less pressure
  - Examples: Fish, sharks





Circuits of double loop

- Two loops
- Systemic circuit-
  - heart → tissues → heart
- Pulmonary Circuit-
  - heart → lungs → heart

Comparison of Circulatory Pathways

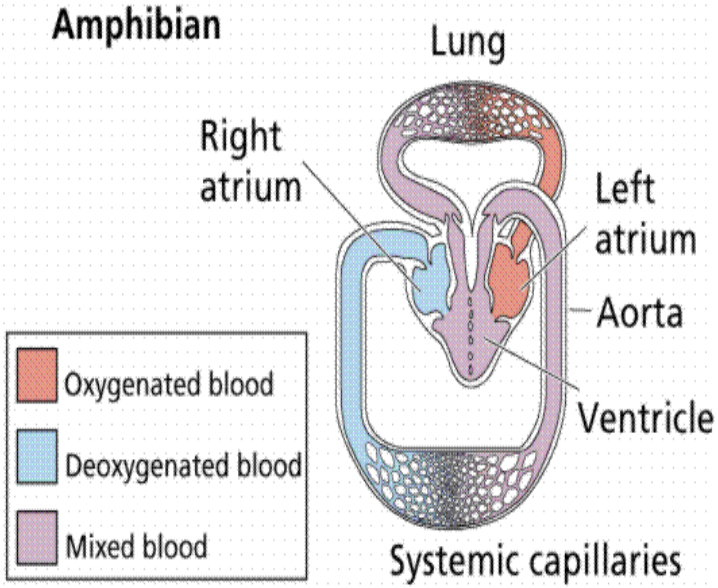
- 3 Chamber heart (Double loop)

  Parts: Two atria and one ventricle.

  Path:

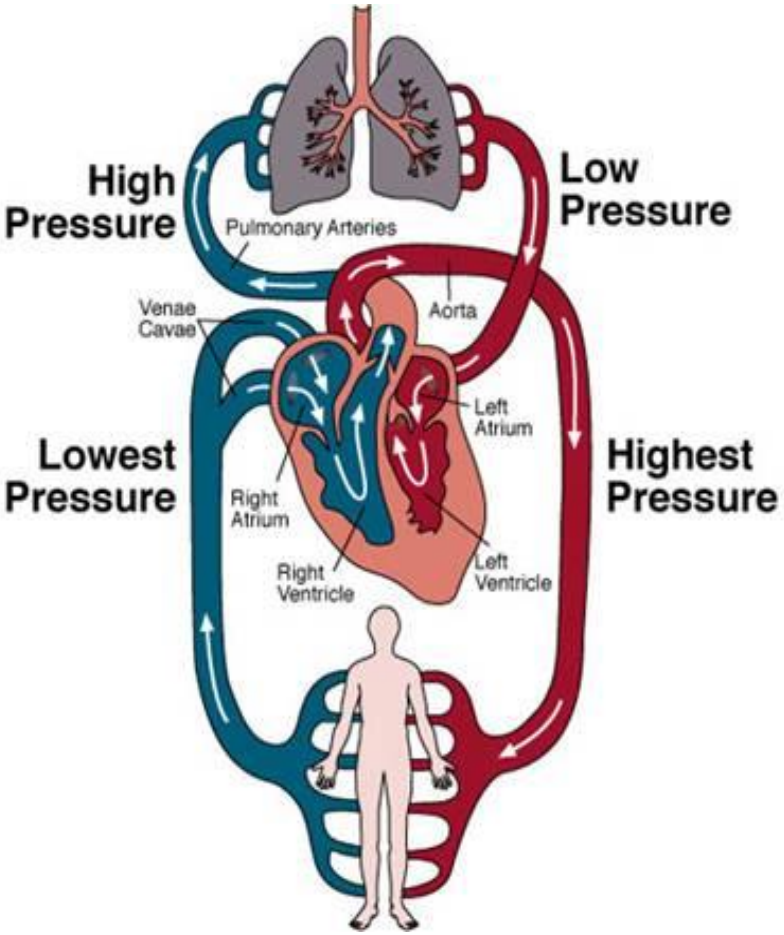
  Rt. Atrium> Ventricle> Lungs> L. Atrium>Body

  - Examples: frogs, salamanders
  - Disadvantage: mixing of blood/ less efficient

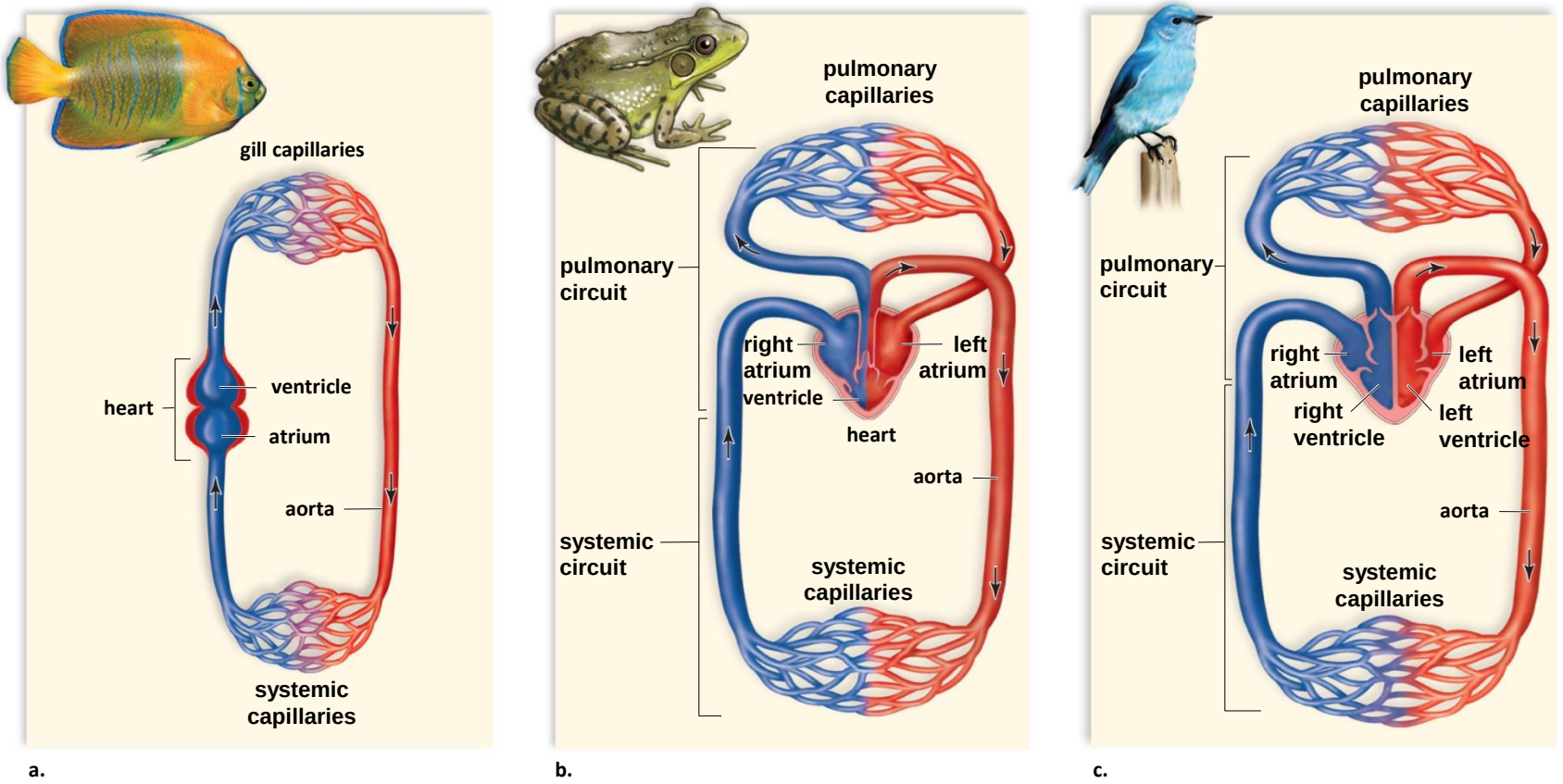


Comparison of Circulatory Pathways

- Four Chambered Heart (Double loop)
  - Parts: Two atria and two ventricles
  - Path: Rt. Atrium → Rt. Ventricle → Lungs → L. Atrium → L. Ventricle → Body
  - Examples: birds, mammals
  - Advantage: no mixing of blood

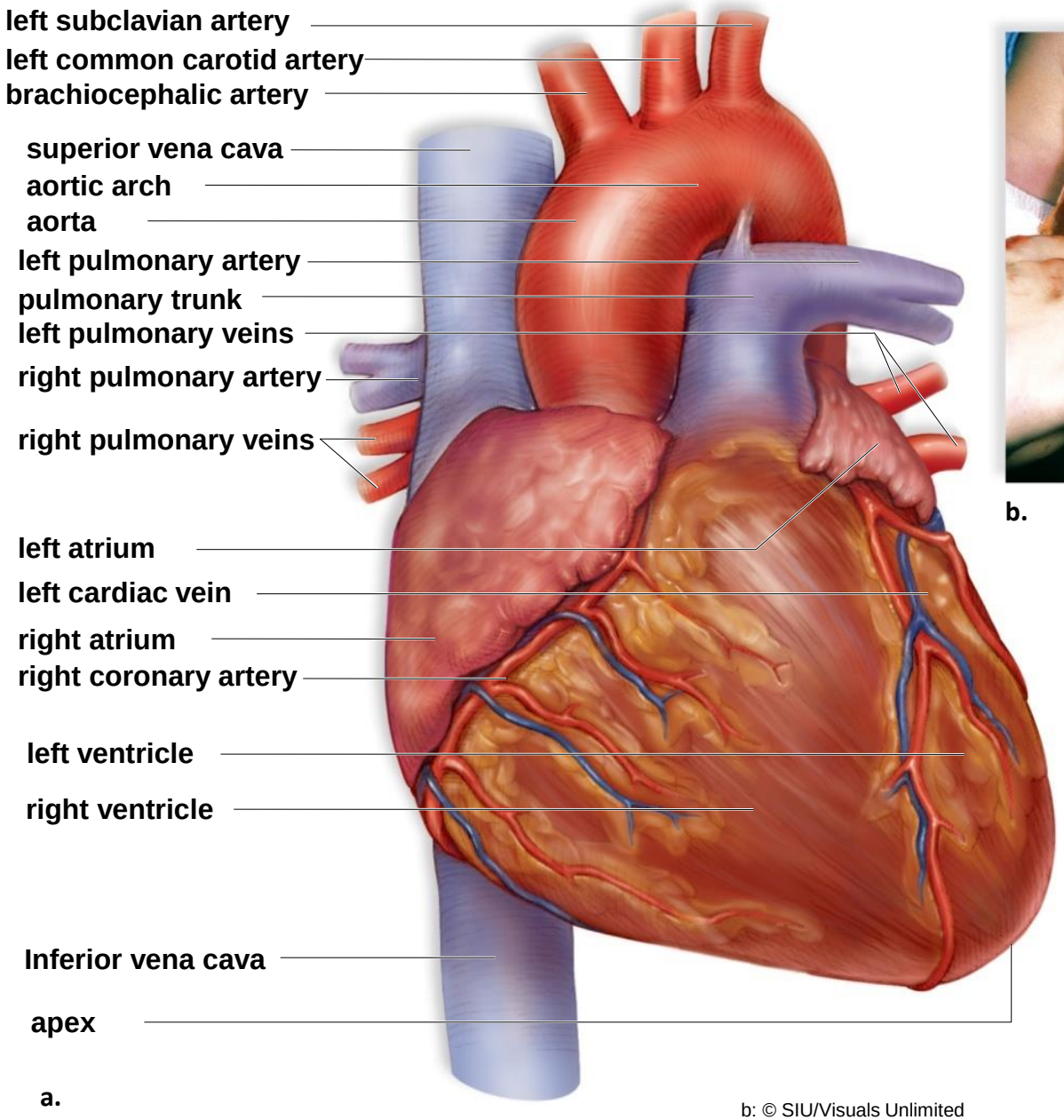


Comparison of Circulatory Circuits in Vertebrates

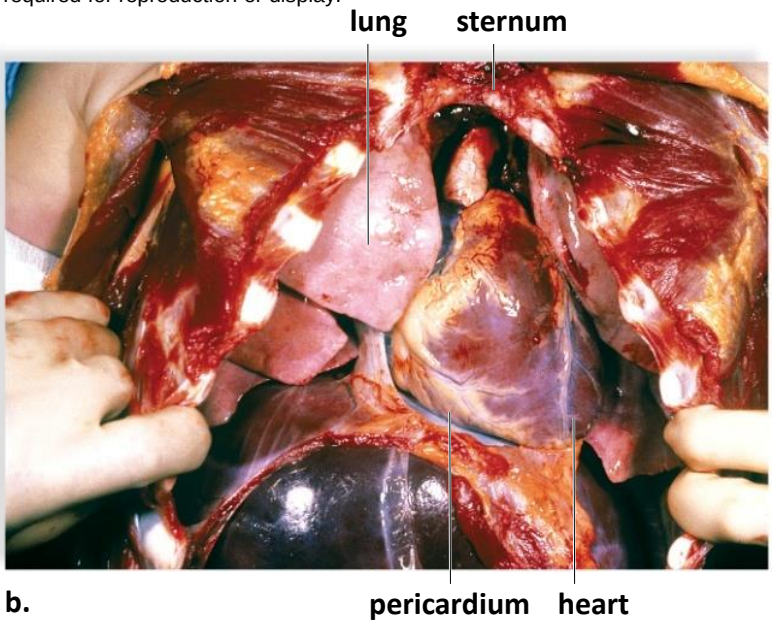


The Human Cardiovascular System

External Heart Anatomy



a.



b.

b: © SIU/Visuals Unlimited

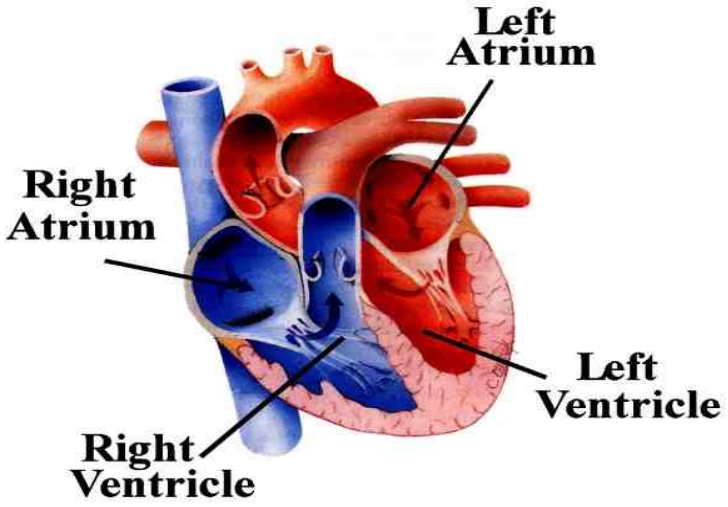
The Heart

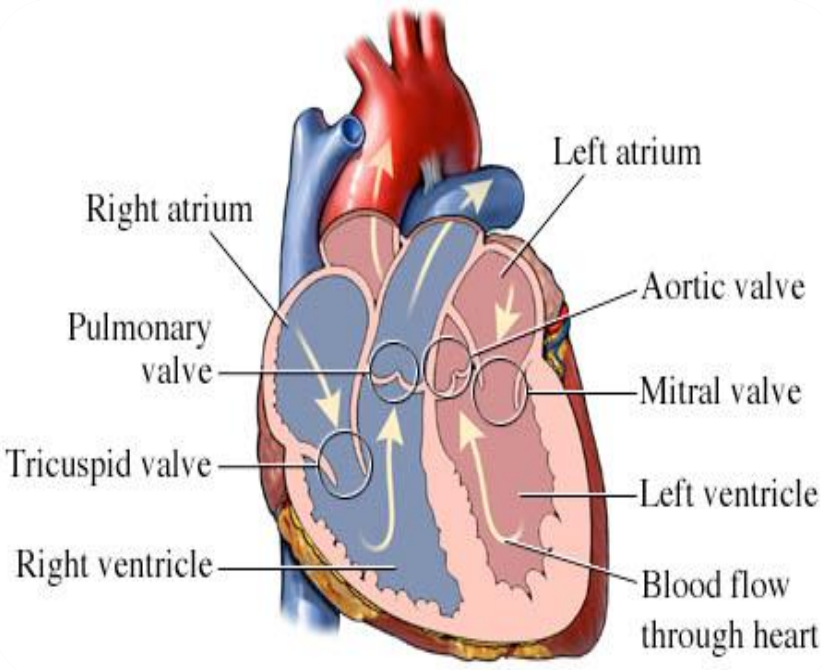
The heart is the vital pump for all the blood in the body. It pumps the blood through two separate parts of the circulation: the pulmonary circulation and the systemic circulation.

It is necessary to pump blood to the pulmonary circulation so that oxygen can be absorbed and carbon dioxide can be released. This blood then gets pumped into the systemic circulation where it can deliver oxygen and uptake wastes.

Heart Anatomy

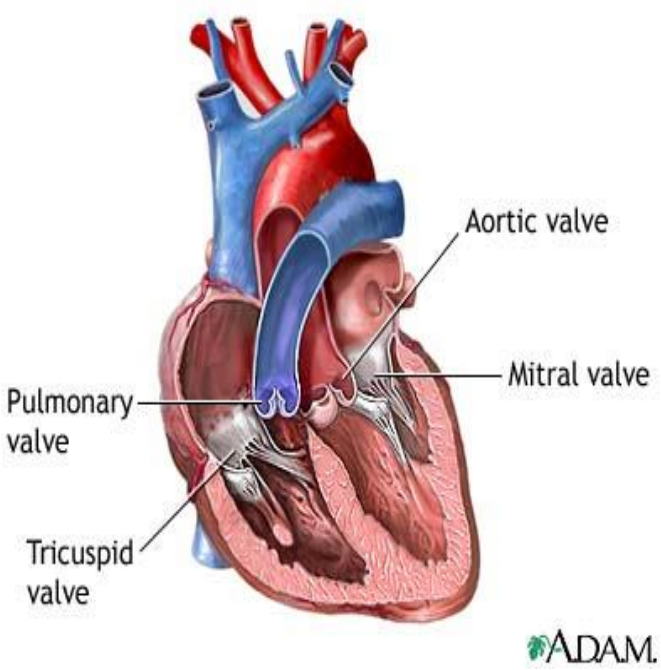
The atria pool blood for a little while before sending it into the ventricles. The ventricles send blood out of the heart, into either the pulmonary or systemic circulations. The right ventricle pumps blood into the pulmonary circulation (via the pulmonary artery), and the left ventricle pumps blood into the systemic circulation (via the aorta)

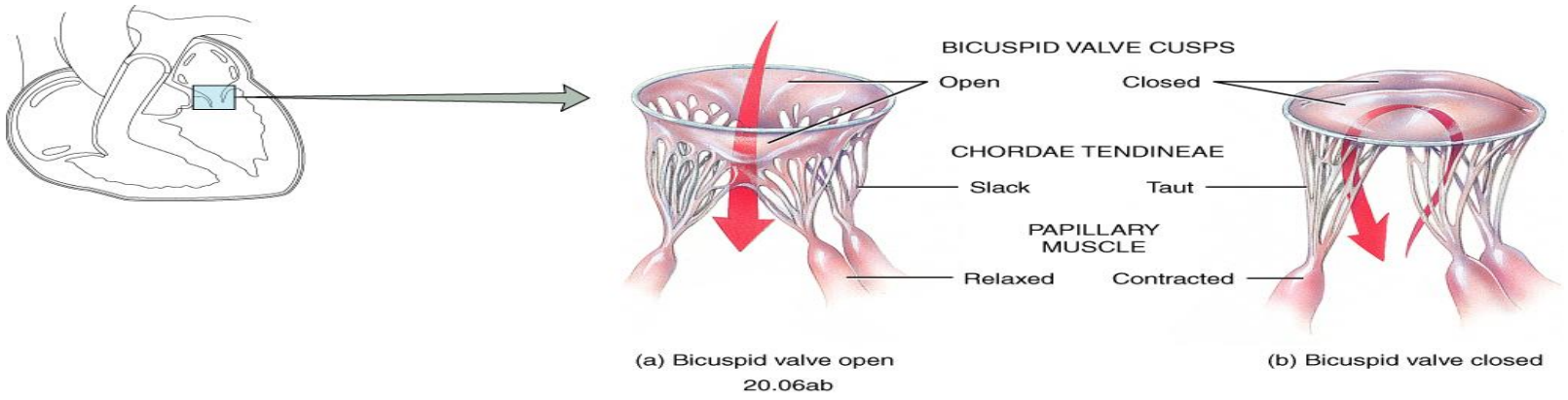




Heart Anatomy

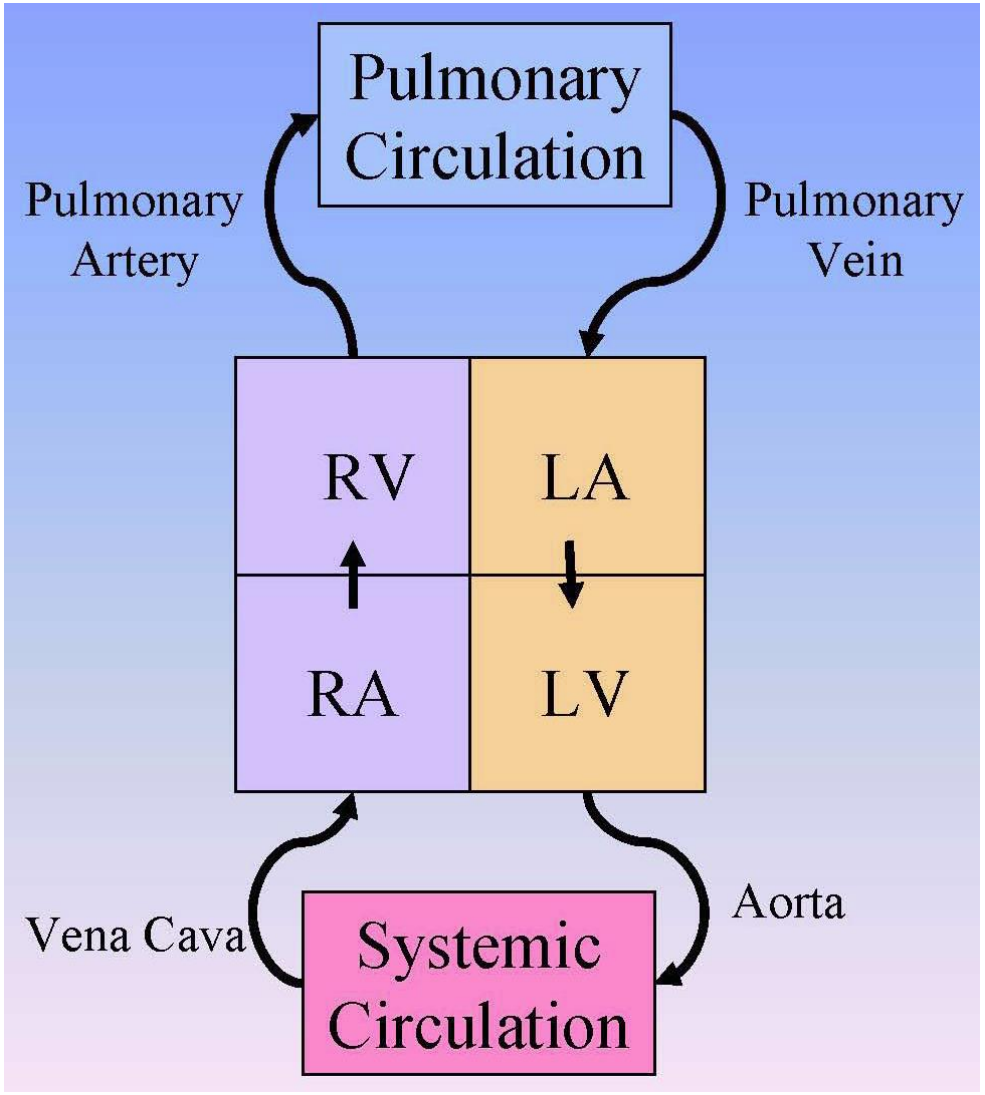
The valves between the atria and ventricles are called atrioventricular valves (AV valves). The right AV valve is also called the tricuspid valve. The left AV valve can also be called the bicuspid valve or the mitral valve. The valves between the ventricles and the aorta/pulmonary artery are called the semilunar valves. The right semilunar valve is known as the pulmonic valve. And the left is the aortic valve.



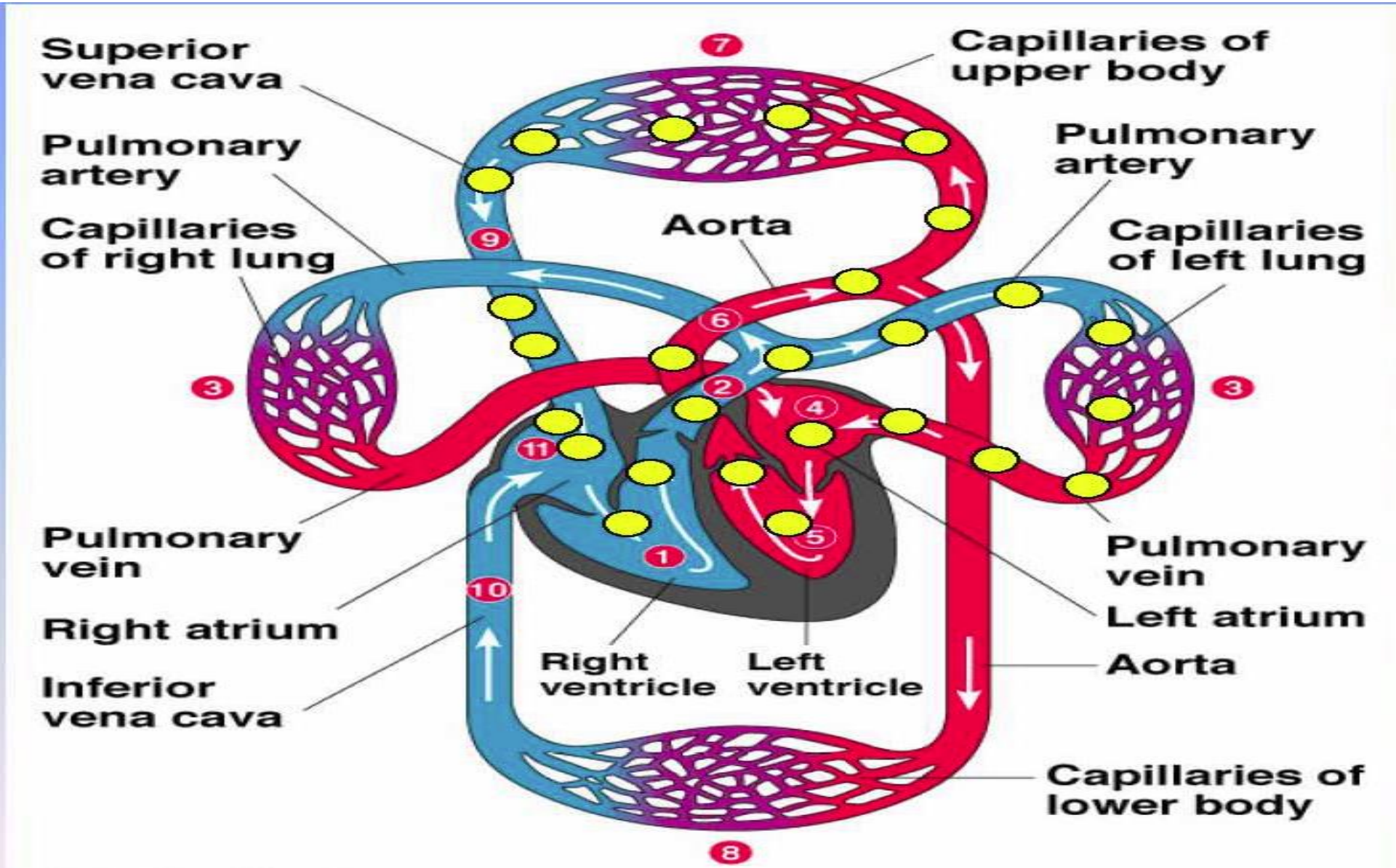


Blood Flow

The valves ensure the blood flows from the right atrium to the right ventricle, through the pulmonary artery into the lungs. The blood comes back from the lungs through the pulmonary vein, and empties into the left atrium. From here, it goes into the left ventricle and is pumped into the aorta and the rest of the systemic circulation. The blood then returns through a large vein called the vena cava.

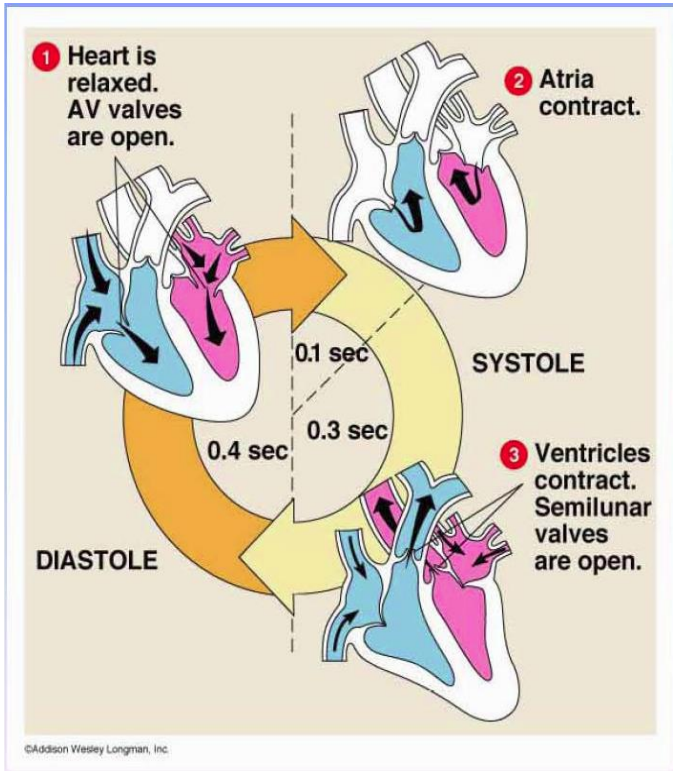


Blood Flow


Superior vena cava
Capillaries of upper body
Pulmonary artery
Pulmonary artery
Capillaries of right lung
Aorta
Capillaries of left lung
Pulmonary vein
Pulmonary vein
Left atrium
Right atrium
Aorta
Inferior vena cava
Right ventricle
Left ventricle
Capillaries of lower body
©Addison Wesley Longman, Inc.

Contraction of Chambers

The heart chambers contract in a coordinated manner, with the atria contracting first, then the ventricles contracting together. When the ventricles are filling, and the atria are contracting, it is called diastole. Systole occurs during ventricular contraction.

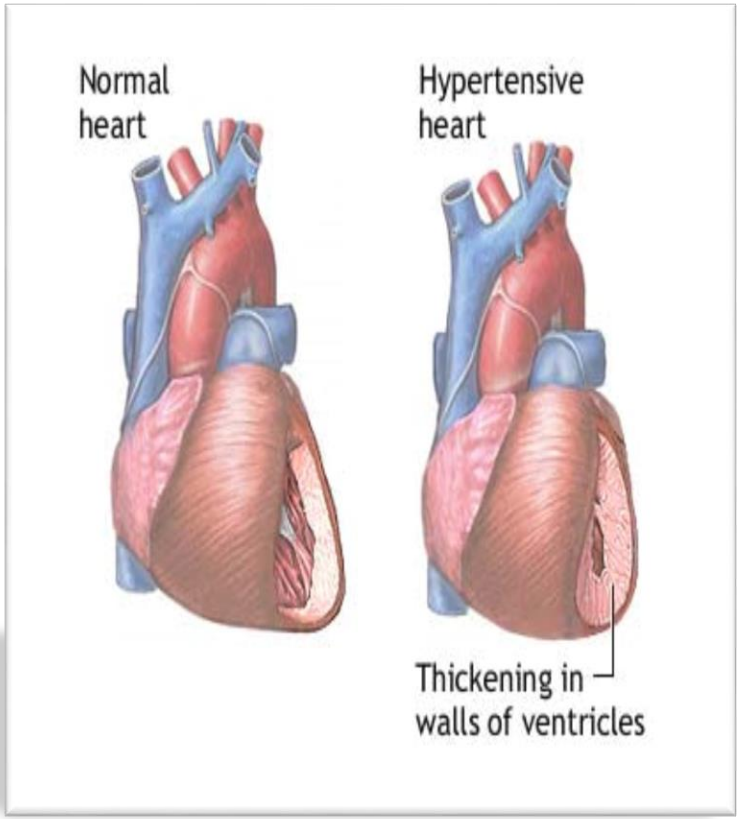


Contraction of Chambers

So when your blood pressure is taken, systolic pressure is the higher pressure (~120 mmHg), during the forceful ventricular contraction. Diastolic pressure is not as great (~80mmHg), since the ventricles are resting and filling at this stage.

<u>Hypertension</u>:

- Systole > 140 and diastole > 90
- Caused by diet high in fat and sodium, obesity, older age, race, heredity, stress, and smoking.
- Consequences: Stroke, impaired vision, arteries and coronary arteries disease, kidney damage, heart attack, congestive heart failure



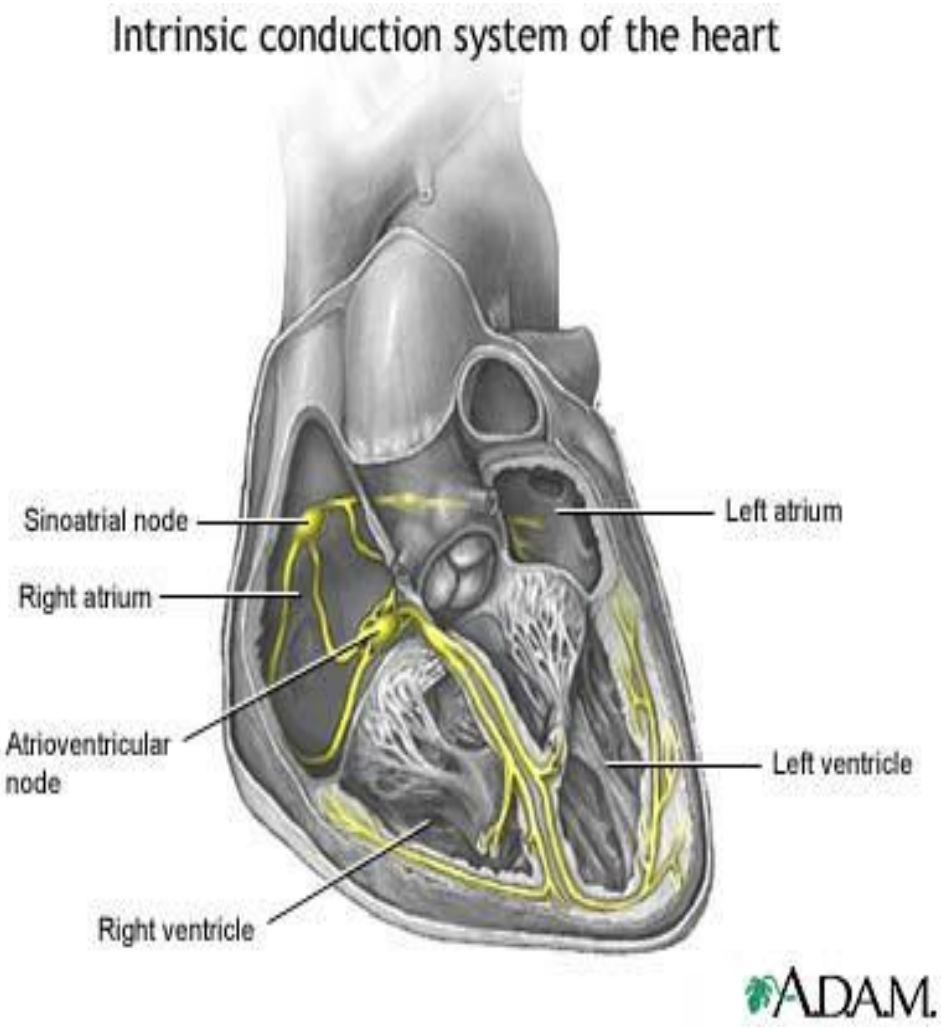
Conduction System of the Heart

1- Sinoatrial node (SA node or pacemaker): hundreds of cells in right atrial wall near opening of superior vena cava

2- Atrioventricular node (AV node): small mass of special cardiac muscle in right atrium along lower part of interatrial septum

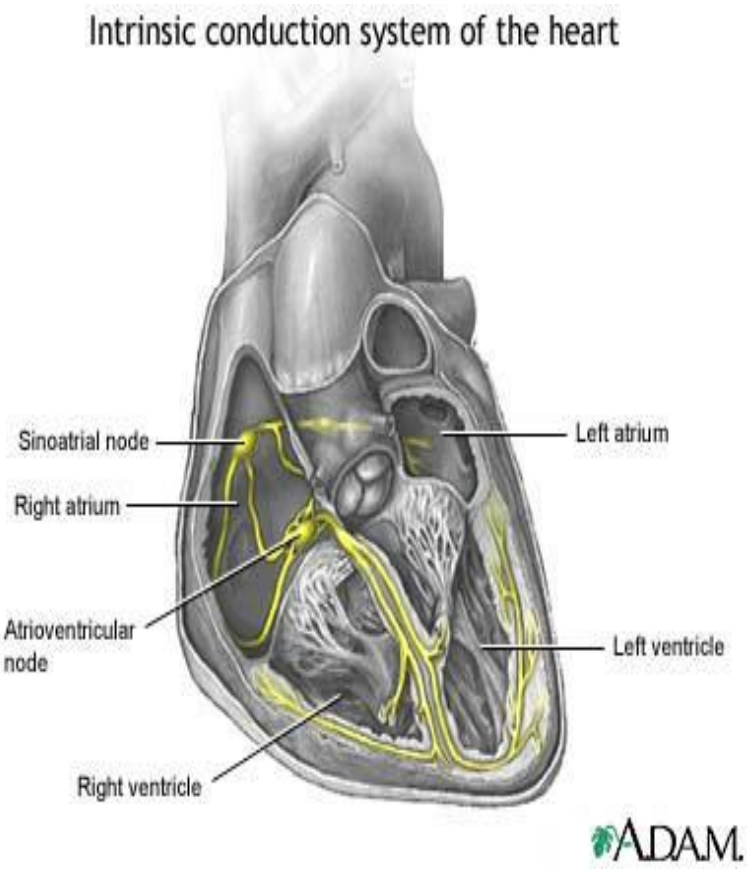
3- Atrioventricular bundle (AV bundle or bundle of His) and Purkinje fibers

- AV bundle originates in AV node, extends by two branches down the two sides of the interventricular septum, and continues as Purkinje fibers
- Purkinje fibers extend out to papillary muscles and lateral walls of ventricles



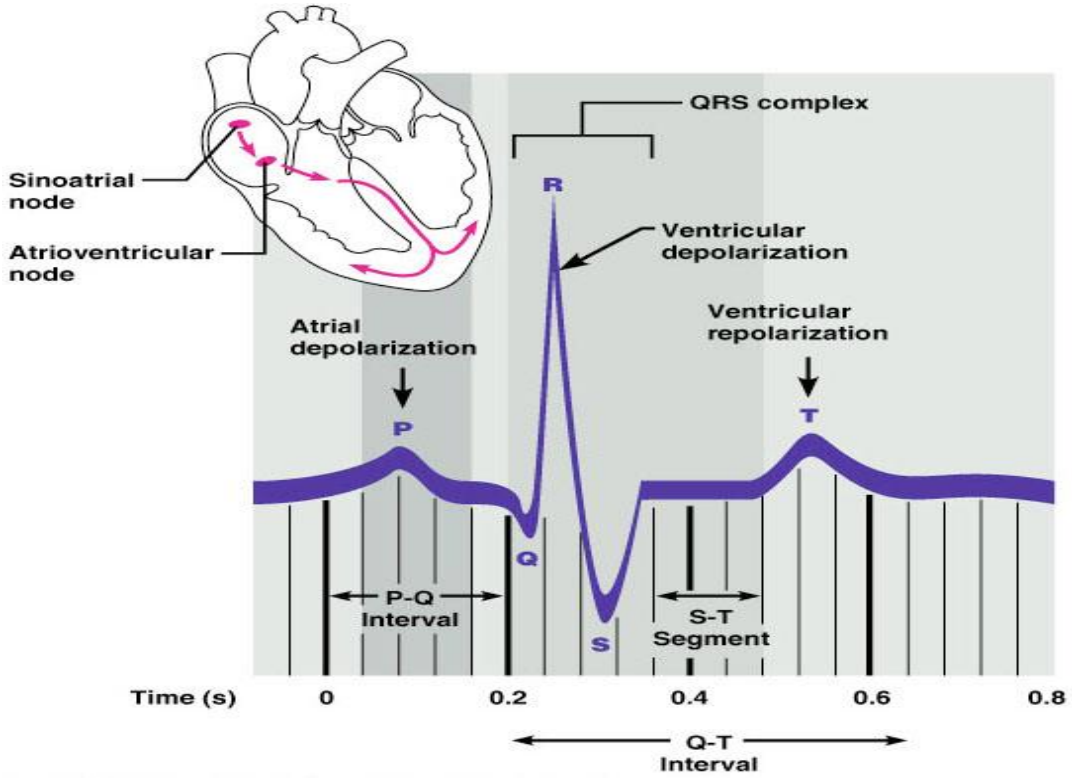
Nerve supply of the heart

- Cardiac plexuses: located near arch of aorta, made up of the combination of sympathetic and parasympathetic fibers
- Fibers from cardiac plexus accompany right and left coronary arteries to enter the heart
- Most fibers end in the SA node, but some end in the AV node and in the atrial myocardium
- Sympathetic nerves: accelerator nerves
- Vagus fibers: inhibitory, or depressor, nerves



Electrocardiography

- Electrical activity is recorded by electrocardiogram (ECG)
- P wave corresponds to depolarization of SA node
- QRS complex corresponds to ventricular depolarization
- T wave corresponds to ventricular repolarization
- Atrial repolarization record is masked by the larger QRS complex



Heart Sounds

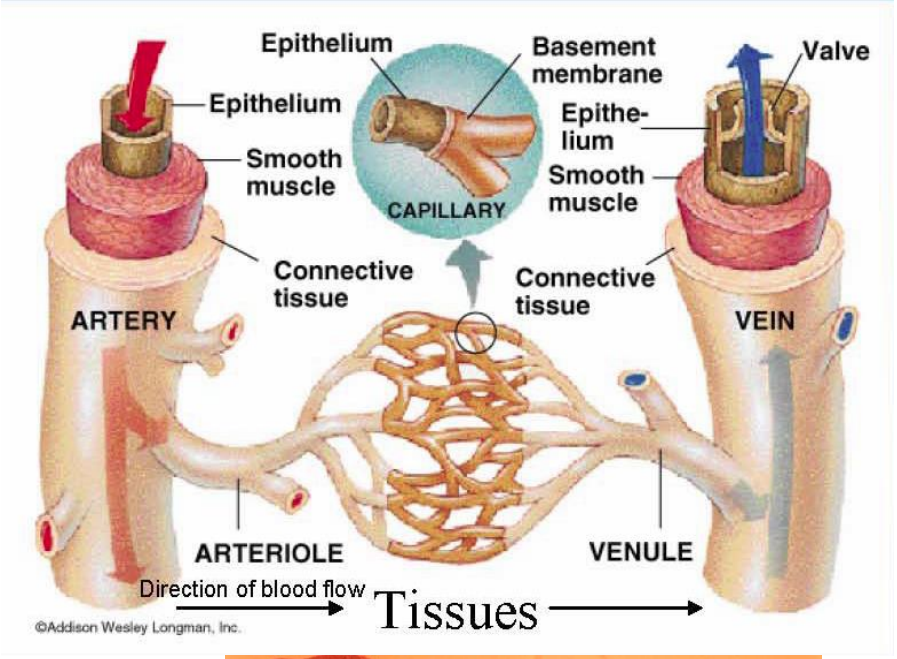
- Heart sounds (lub-dup) are associated with closing of heart valves
  - First sound occurs as AV valves close and signifies beginning of systole
  - Second sound occurs when SL valves close at the beginning of ventricular diastole

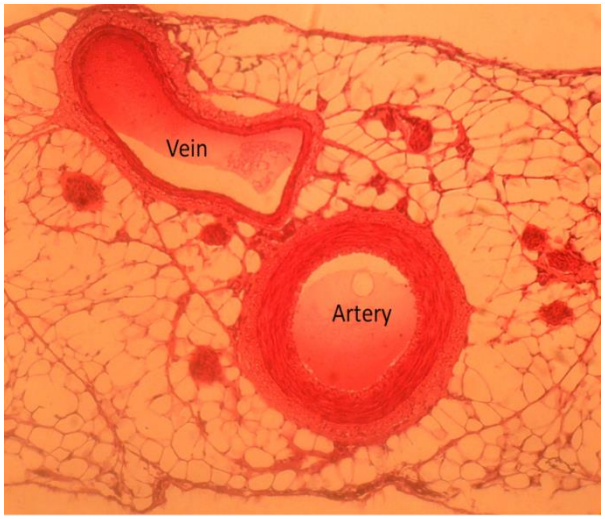
Blood Vessels

Arteries and arterioles carry blood away from the heart, towards the circulation (pulmonary or systemic). Veins and venules carry blood towards the heart, away from the circulation (pulmonary or systemic). Between the arteries and veins, gases and nutrients are exchanged in capillary beds.

Characteristics of Blood Vessels

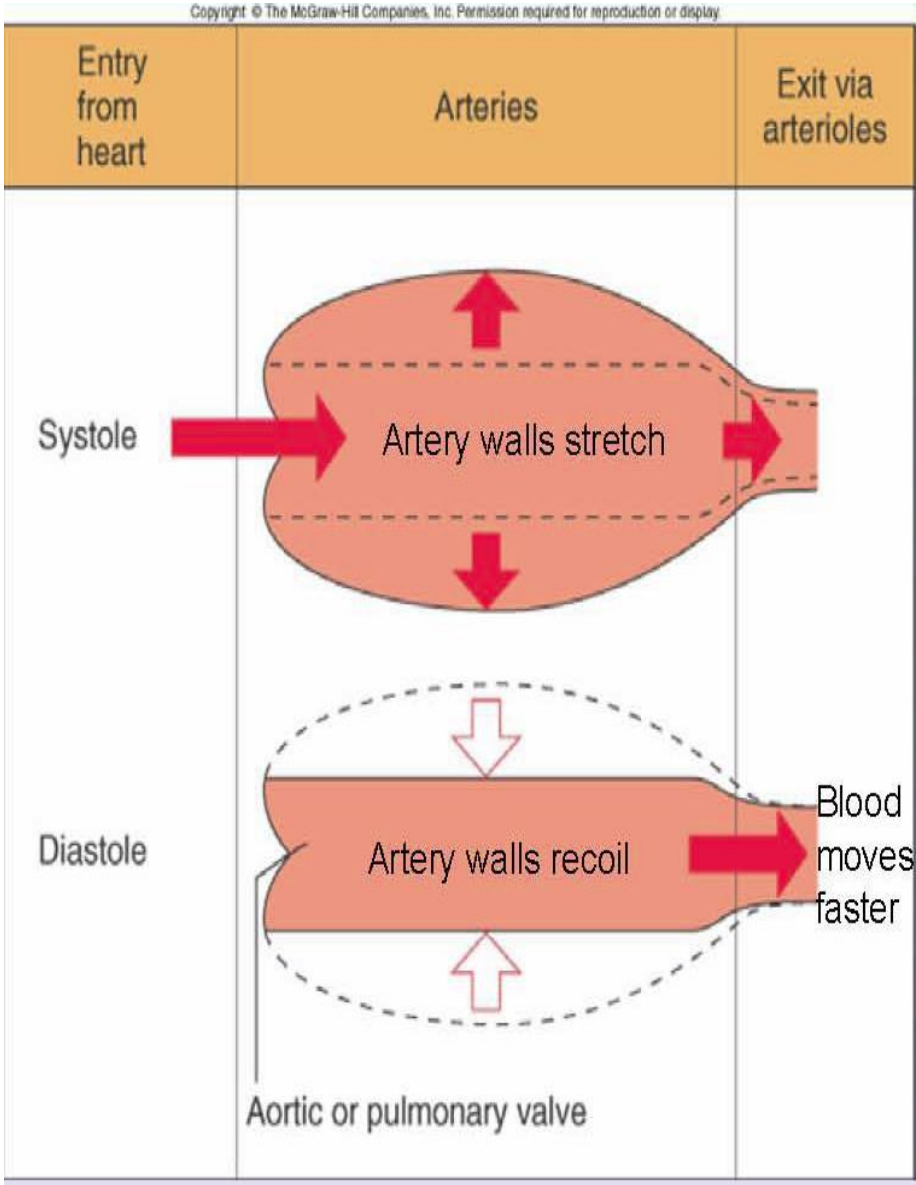
Arteries and the smaller branches arterioles, carry blood towards the tissue. Arteries are very elastic and have lot of smooth muscle around them. Capillaries do not have muscle around them. Instead, they have very thin walls so that gases and nutrients can diffuse across the walls into/out of the tissues. Veins are very compliant (they stretch), though they are not elastic (no recoil). They ensure blood keeps moving towards the heart by many one-way valves inside them.





Arterial Pressure

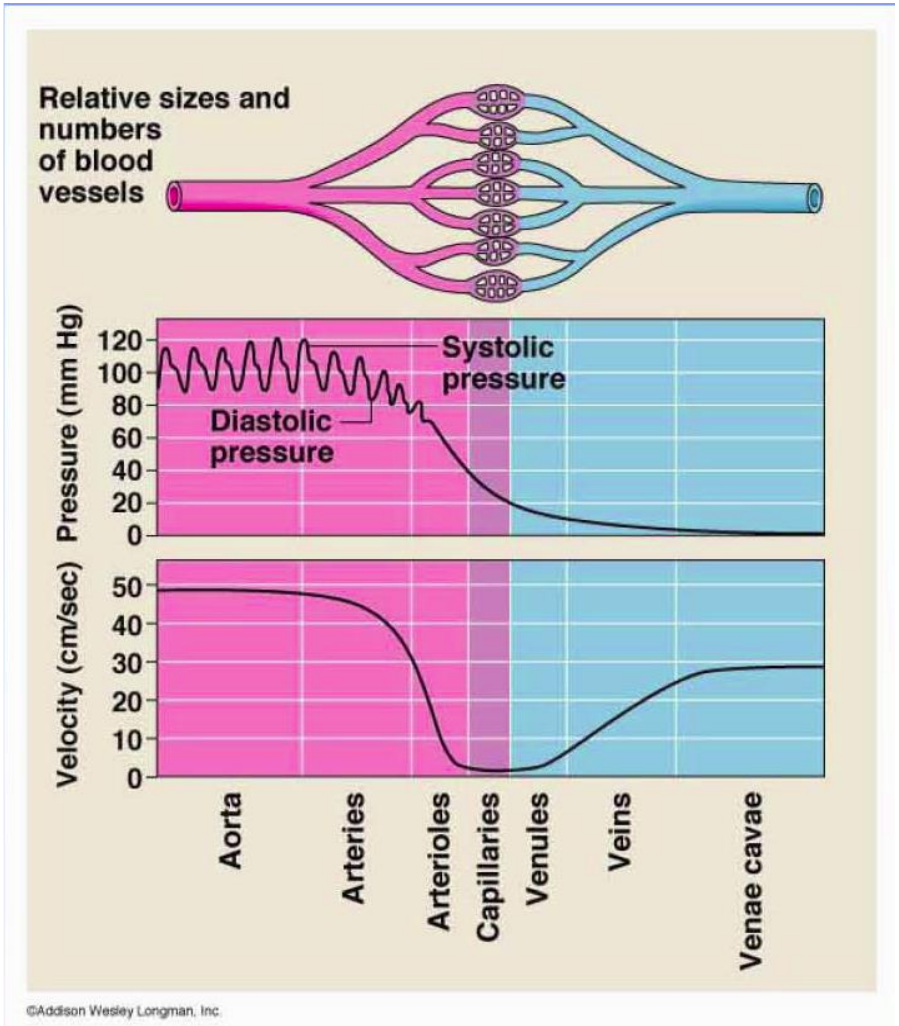
Because arteries are very elastic, they maintain the high pressure initially produced by the heart: the artery walls get stretched by the extra volume of blood, and then recoil, pushing the blood forward. This mechanism works similarly to that of a balloon filled with water then released, untied: the water would be expelled from the balloon as the walls of the balloon recoil.



Blood Pressure

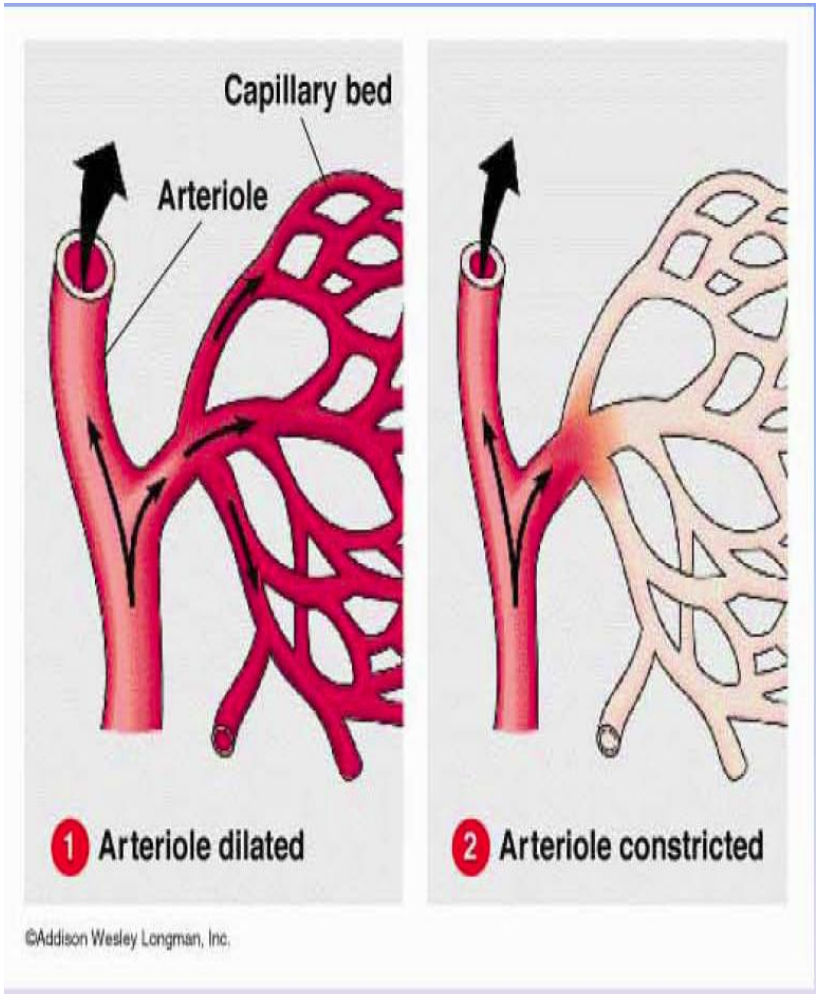
The graph to the right is showing blood pressure in the different blood vessels. The high pressure can be maintained through the arteries. But once the blood reaches the arterioles, which are not as elastic, the pressure drops significantly!

By the time the blood reaches the capillaries, the pressure is almost zero, and velocity is very small. The slow speed of the blood is important to give enough time for gases and nutrients exchange.



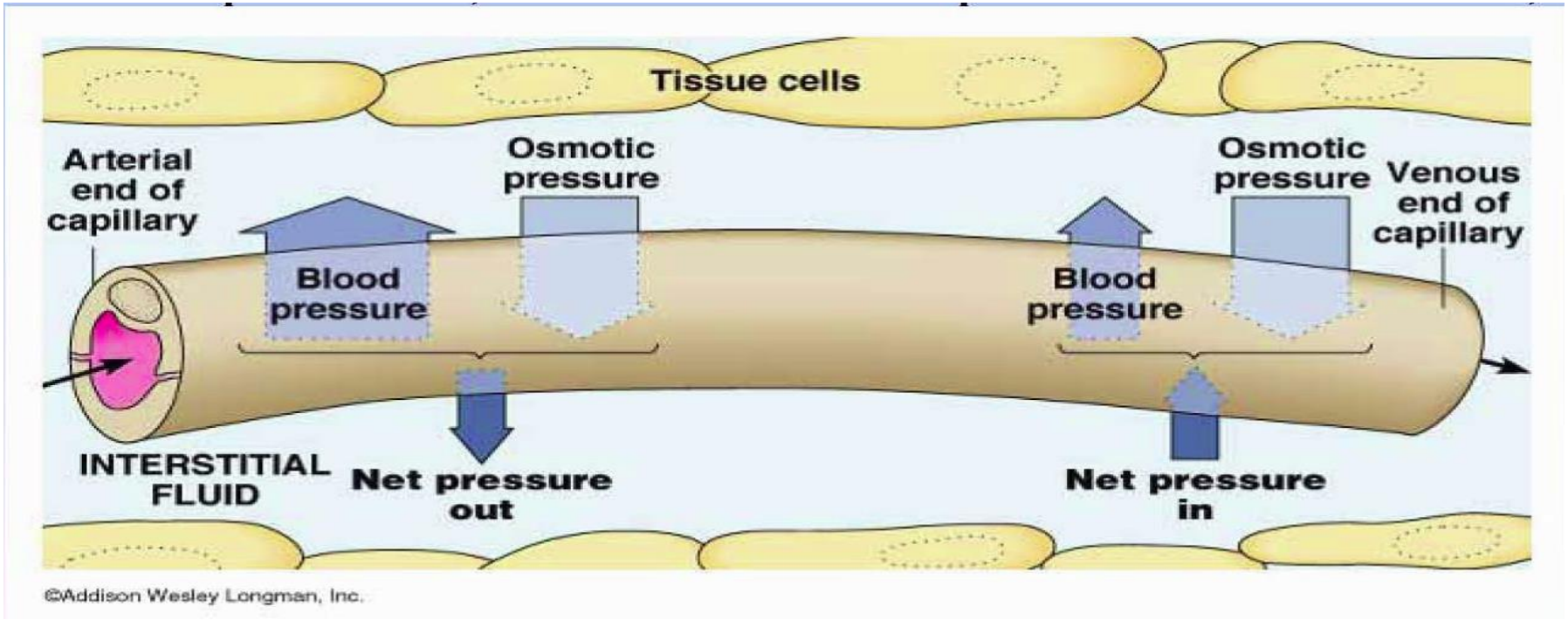
Arterioles

Although the arterioles are net very elastic, they control blood flow at the organ/tissue level. If a certain tissue does not need as much blood, the smooth muscle around the arteriole can constrict, limiting blood flow to that area. If a tissue/organ needs more blood, the smooth muscle surounding the local arteriole can relax, letting blood flow freely to that tissue or organ.



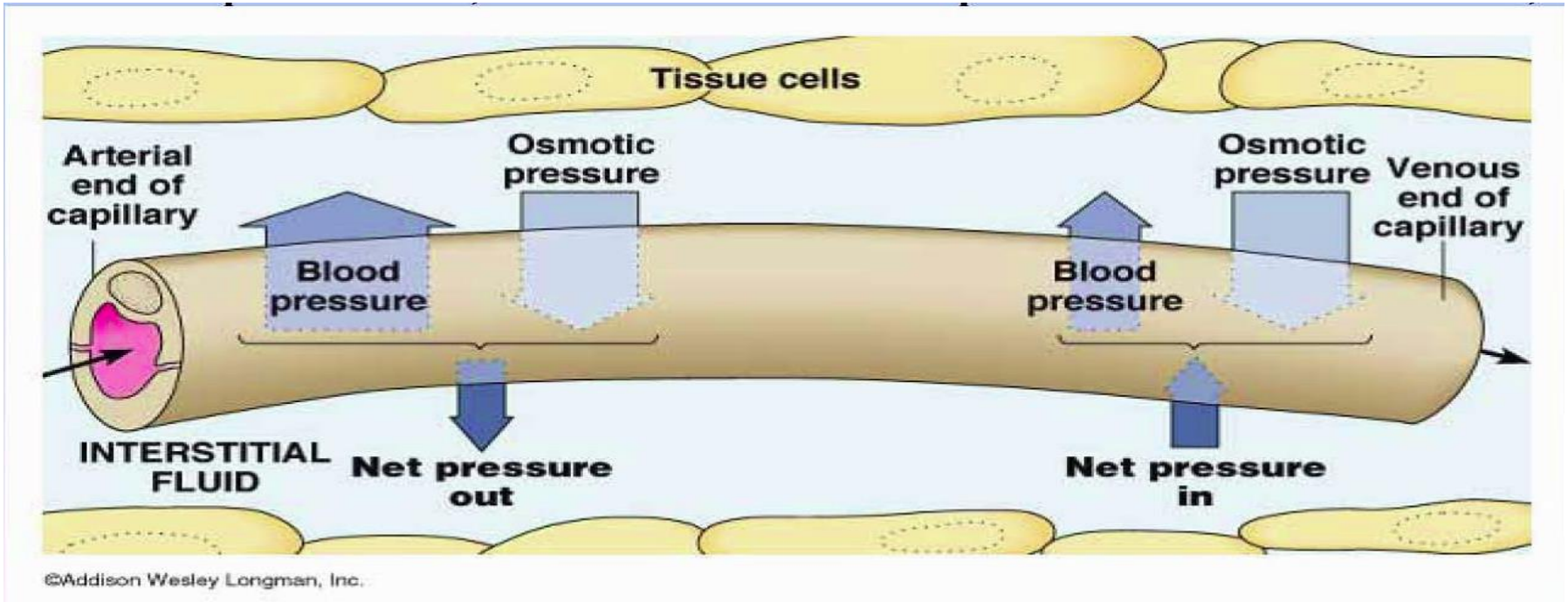
Capillary Exchange

In the capillaries, fluids filled with nutrients need to leave the capillary, and fluids containing waste materials from the tissue must enter the capillary. This exchange of fluid depends on two pressures: blood pressure pushing out of the capillary and osmotic pressure pushing fluid into the capillary.

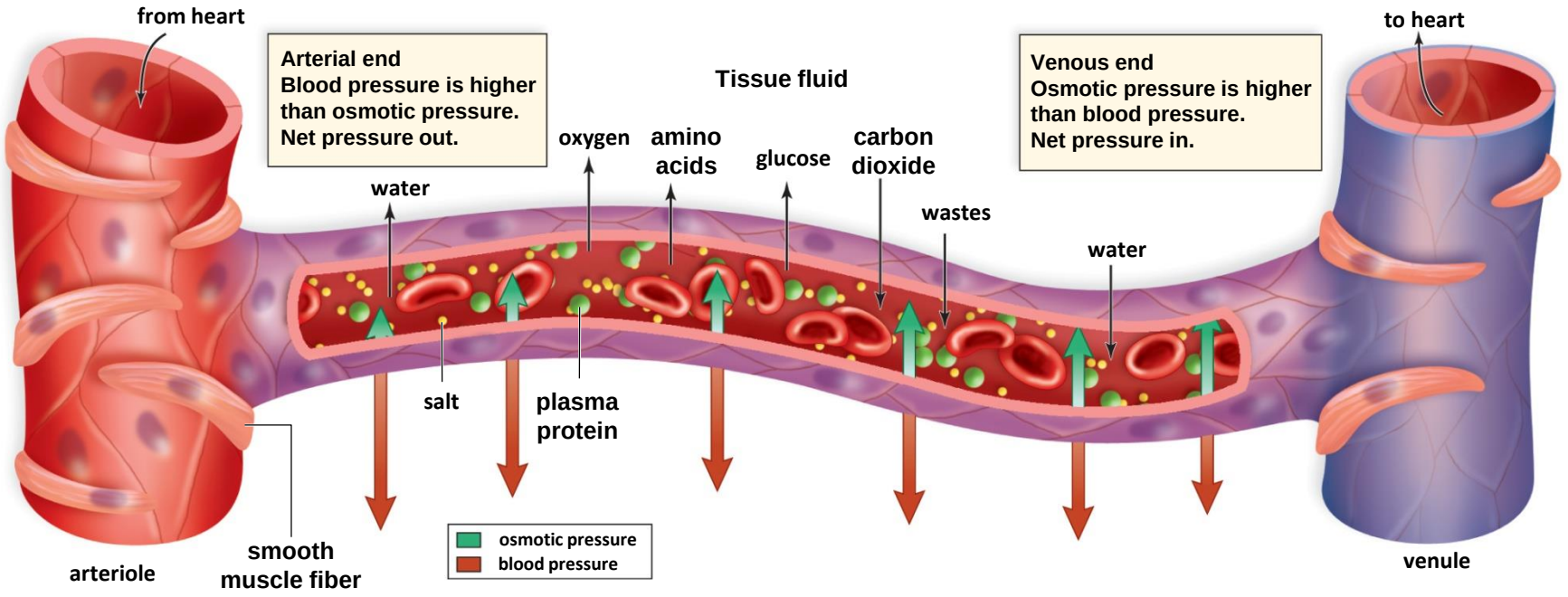


Capillary Exchange

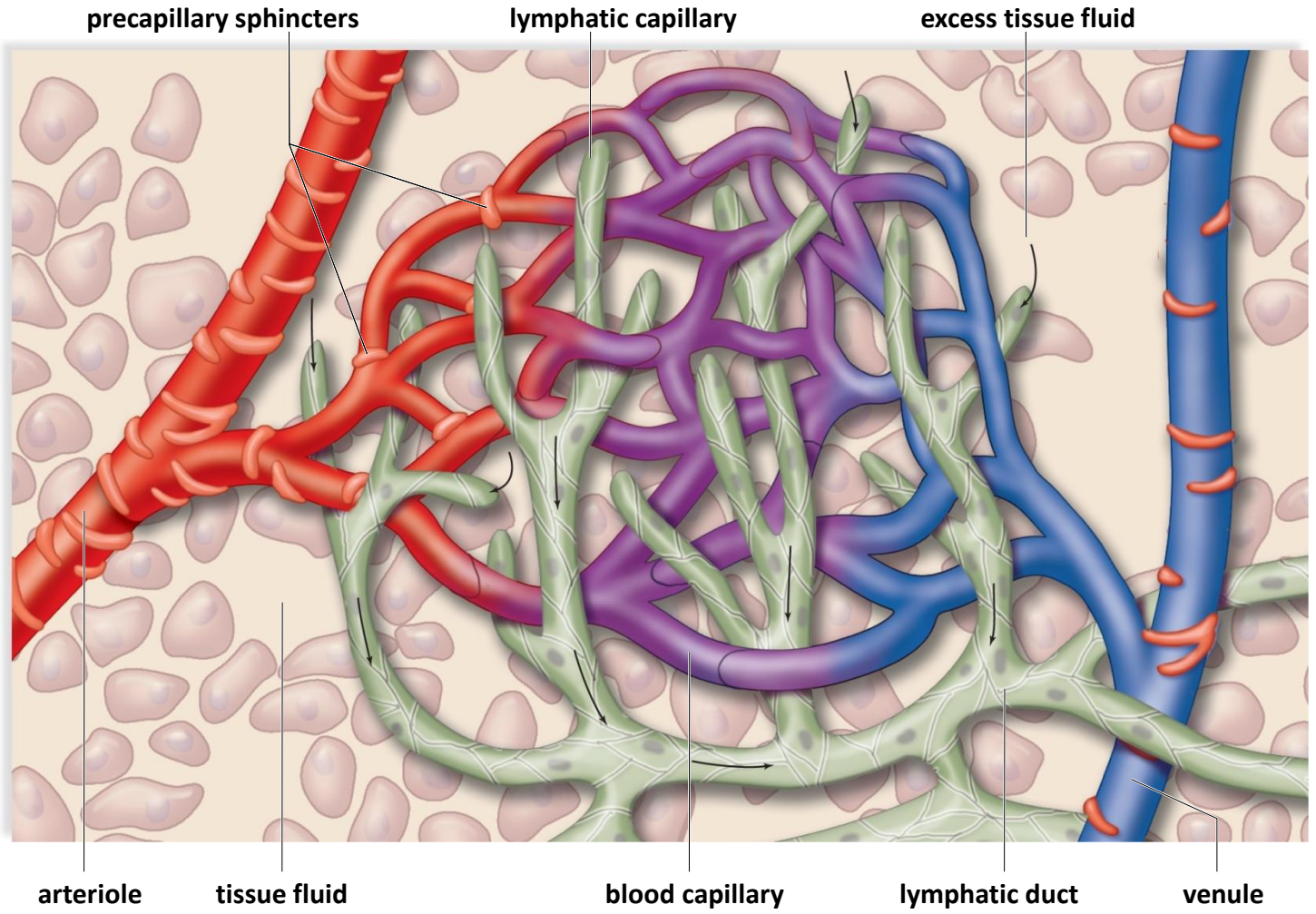
The arterial end of the capillary has a relatively high blood pressure compared to the surrounding pressure wanting to enter the capillary via osmosis. Therefore, at the beginning of the capillary, the net movement favors fluid movement out towards the tissues. The end of the capillary now has a very low volume, and therefore low blood pressure, so the osmotic pressure takes over, forcing fluids in.



Capillary Exchange

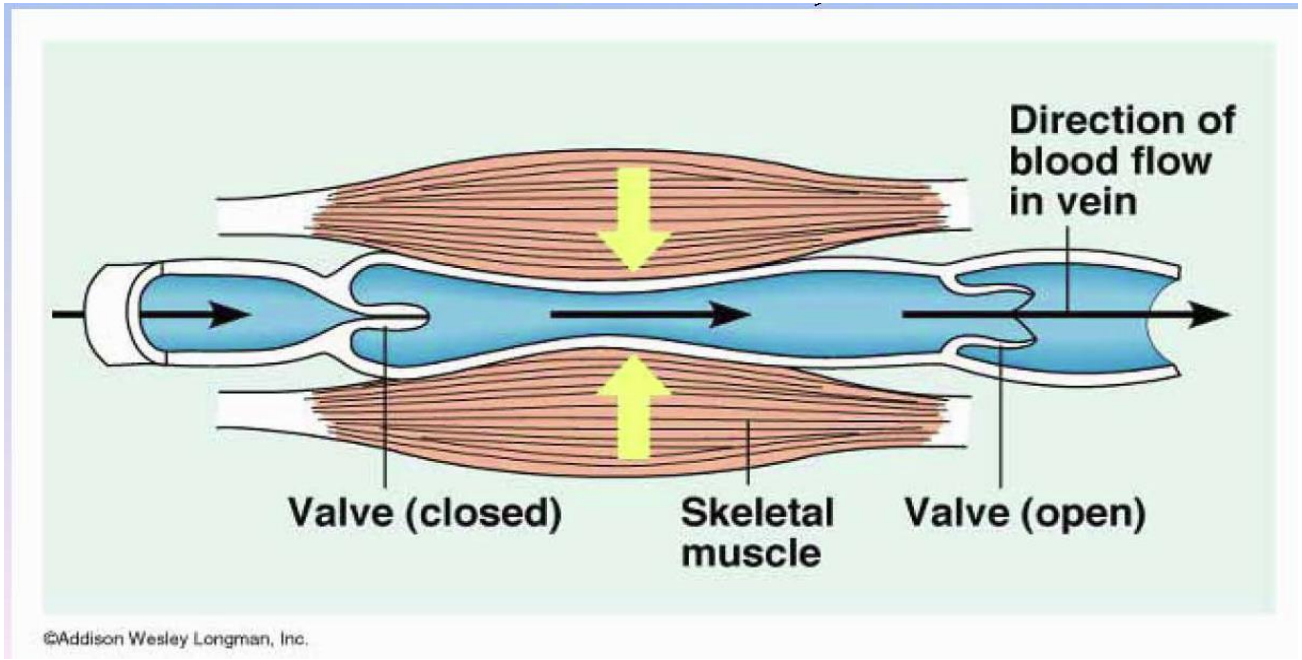


Capillary Bed



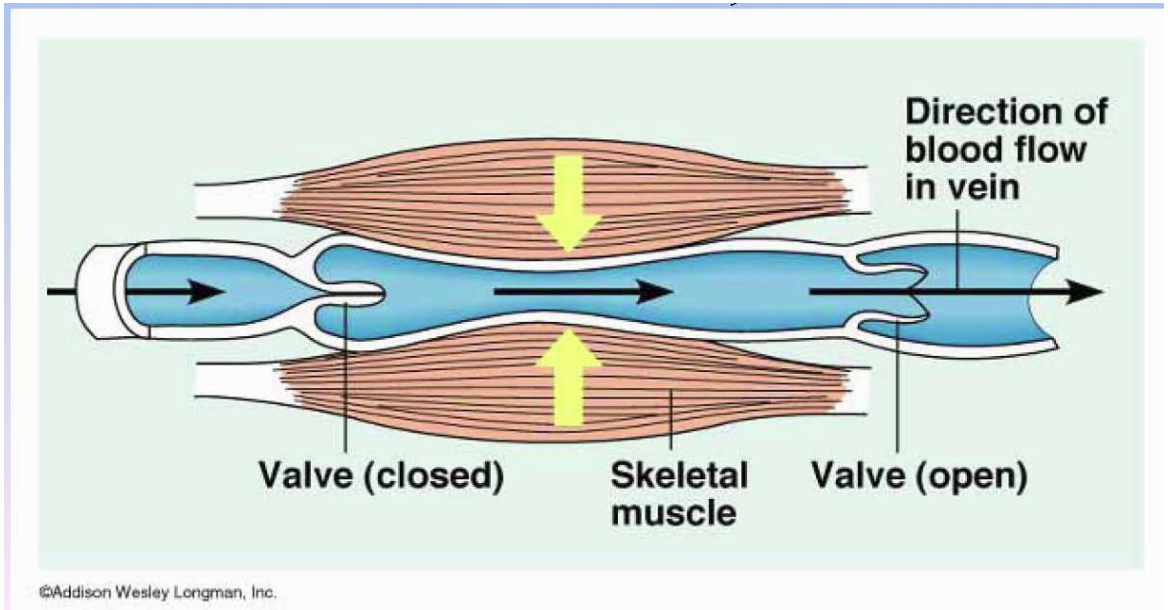
Veins

After capillaries exchange fluids, the veins need to bring the leftovers back towards the heart. But remember that after the capillaries, we had very little, if not any blood pressure! So how can the veins pump the blood back towards the heart?



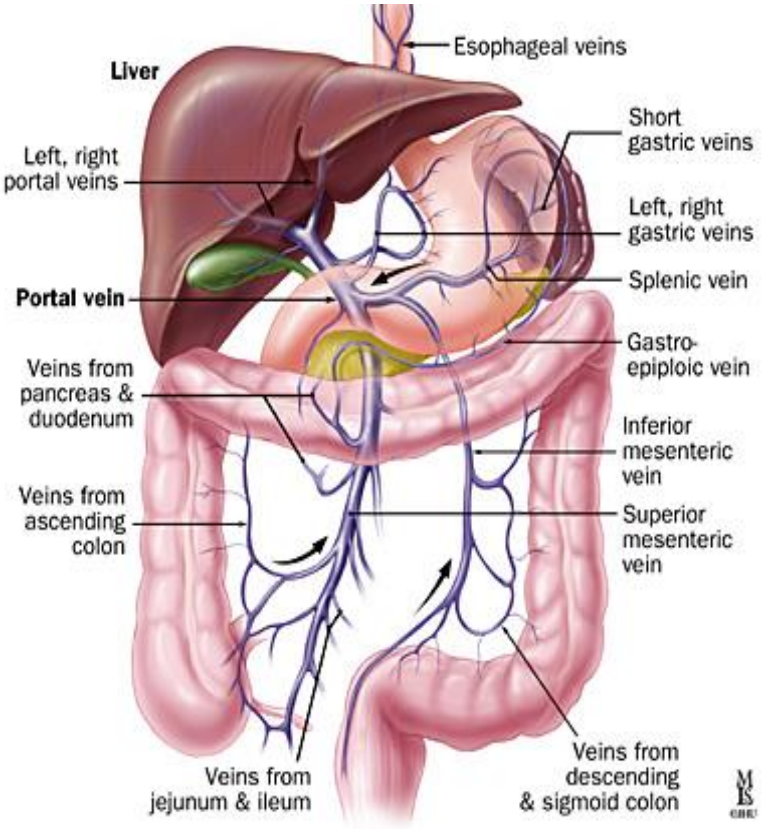
Veins

The skeletal muscles pump: veins run between skeletal muscles, and when the muscles contract and widen, they push the blood along the veins by squeezing the walls of the vein inwards. Because the veins are fitted with one-way valves, the blood is sure to move in the right direction. This is way if a person is on bed rest or does not walk much, fluid can collect in the legs and feet.



Portal Circulation

- Capillaries in the intestines and stomach take up nutrients from recently eaten foods.
- These capillaries merge into veins that empty into the portal vein.
- Portal vein leads to the liver
- Liver processes the absorbed nutrients before they enter the general circulation, take nutrients that it needs and kill bacteria and other microorganisms by macrophages



Development of cardiovascular disease

Occurs slowly, plaque build up can begin in childhood

Associated with inadequate blood circulation from plaque build up

1- Myocardial infarction (heart attack)

- Blood flow surrounding the heart is interrupted.

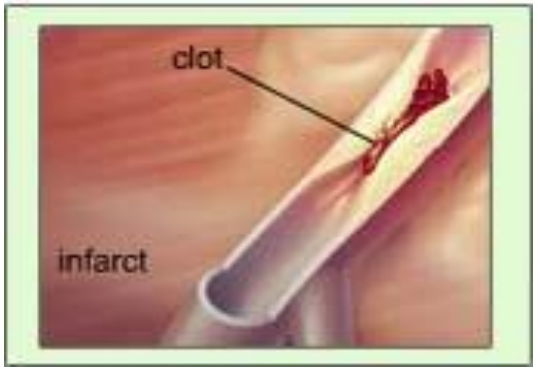
- Irregular or cessation of heart beat

2- Cerebrovascular accident (CVA, brain)

- Blood flow to part of the brain is interrupted

- Part of the brain may die

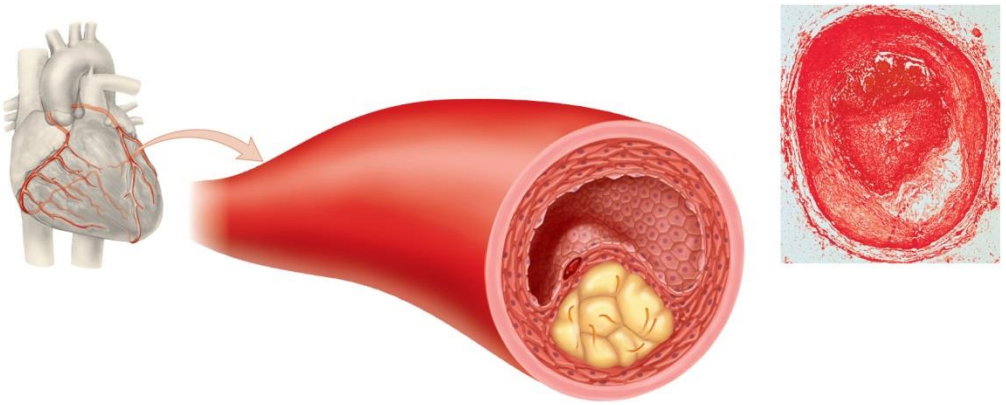
- Also called stroke



Development of cardiovascular disease

3- Atherosclerosis: development of plaque

- Plaque formation increases likelihood of clots forming
- 95% of all heart attacks are caused by these clots
- First develops to repair damage of a vessel lining that can be caused by smoking, diabetes, hypertension, LDL or infections
- Oxidized LDL contributes to plaque
  - Antioxidants in food (not supplements) can reduce oxidation of LDL and reduce plaque build up
  - Vit E supplementation may help



The Human Cardiovascular System

- **Stroke** - Cranial arteriole bursts or is blocked by an embolus
- **Heart attack** (myocardial infarction) – Coronary artery becomes completely blocked
- **Angina pectoris** – Painful squeezing sensation from myocardial oxygen insufficiency due to partial blockage of a coronary artery