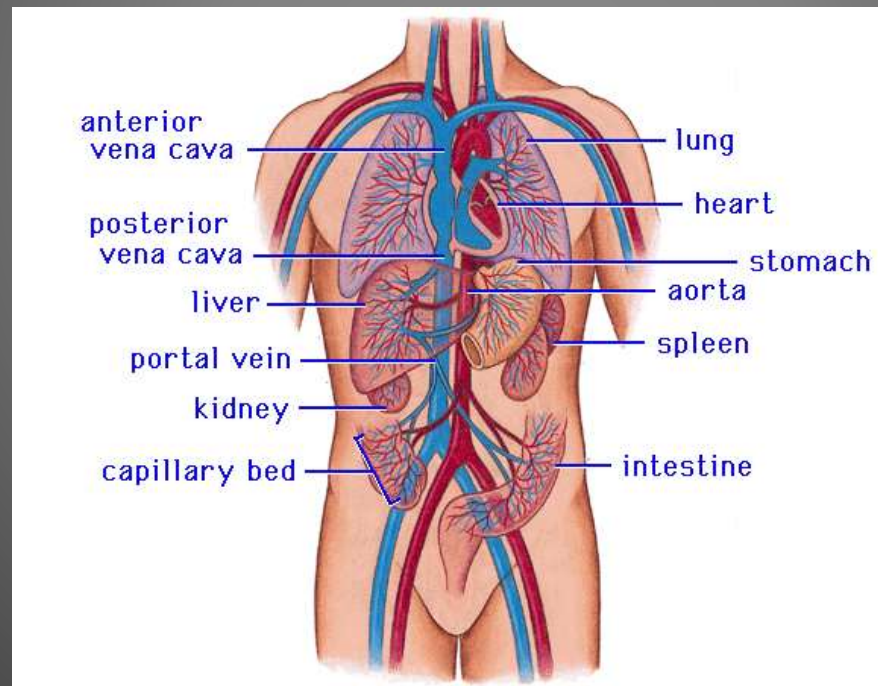
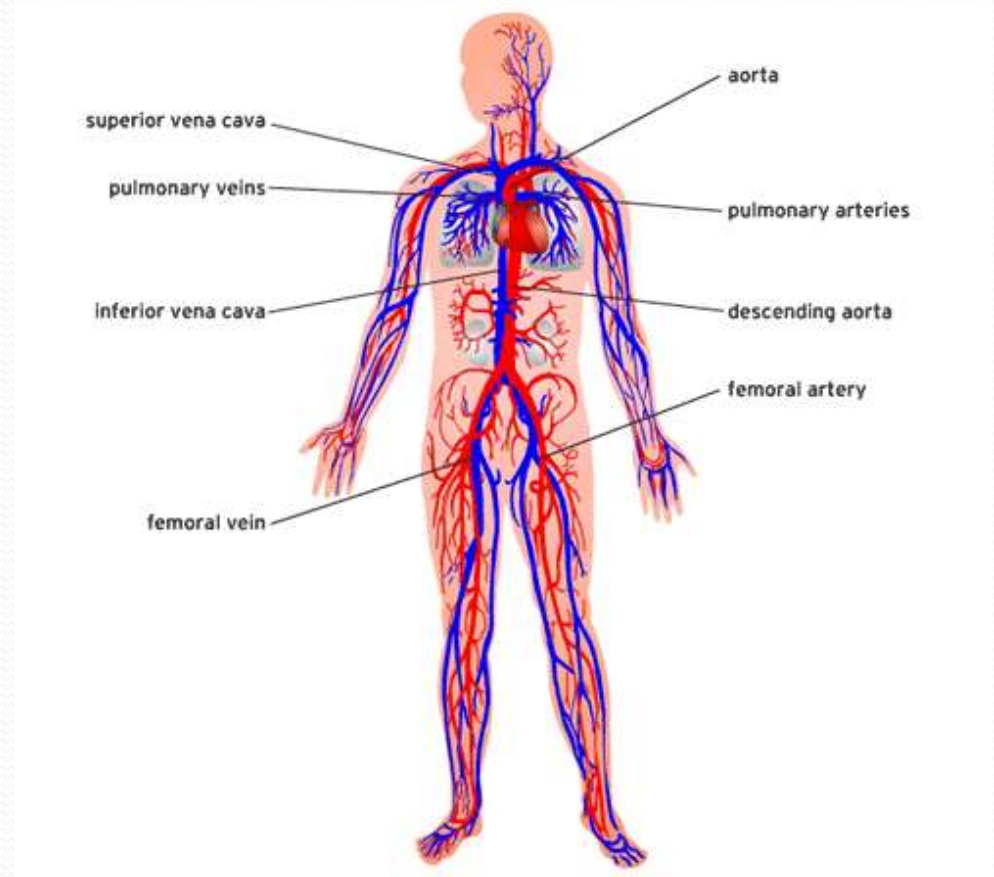


The Cardiovascular System



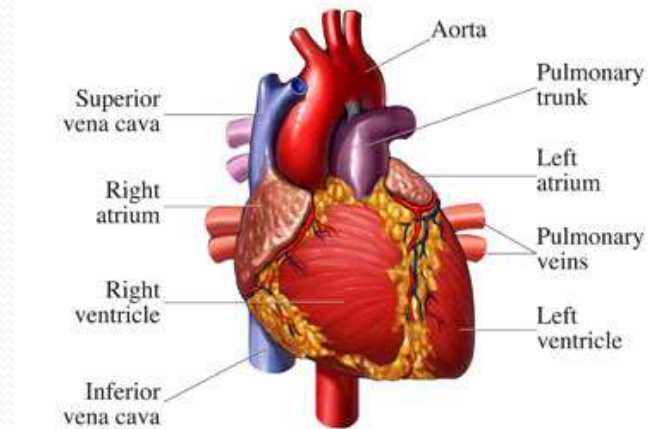
The Cardiovascular System

- Cardiovascular system: organ system that distributes blood to all parts of the body
- Major function – transportation, using blood as the transport vehicle

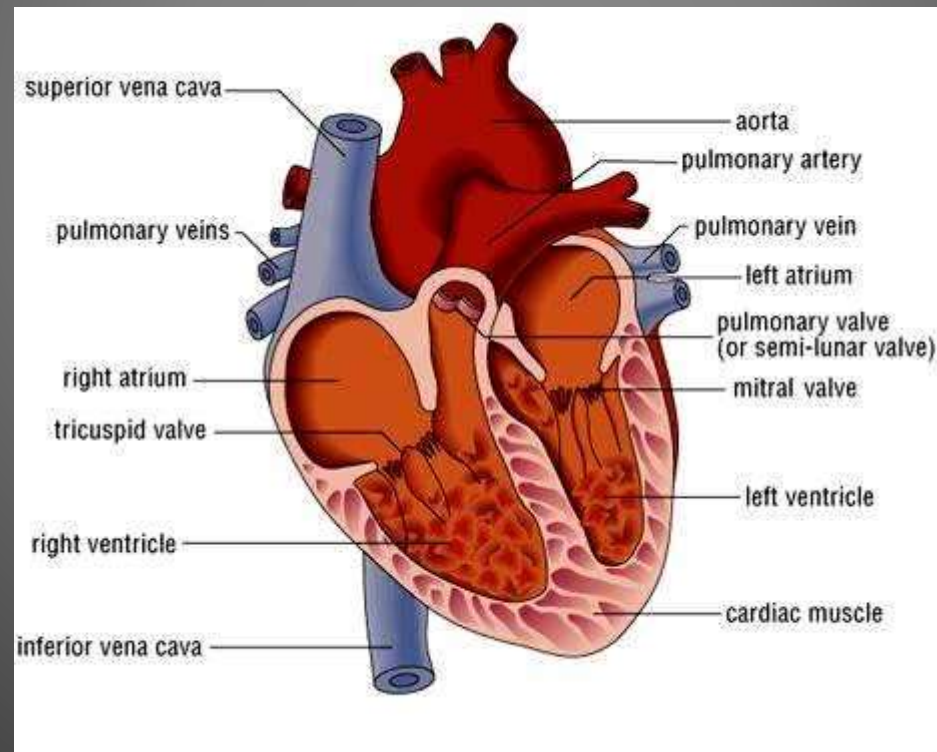


The Cardiovascular System

- This system carries oxygen, nutrients, cell wastes, hormones and other substances vital for body homeostasis to and from cells
- The force to move blood around the body is provided by the pumping heart and blood pressure

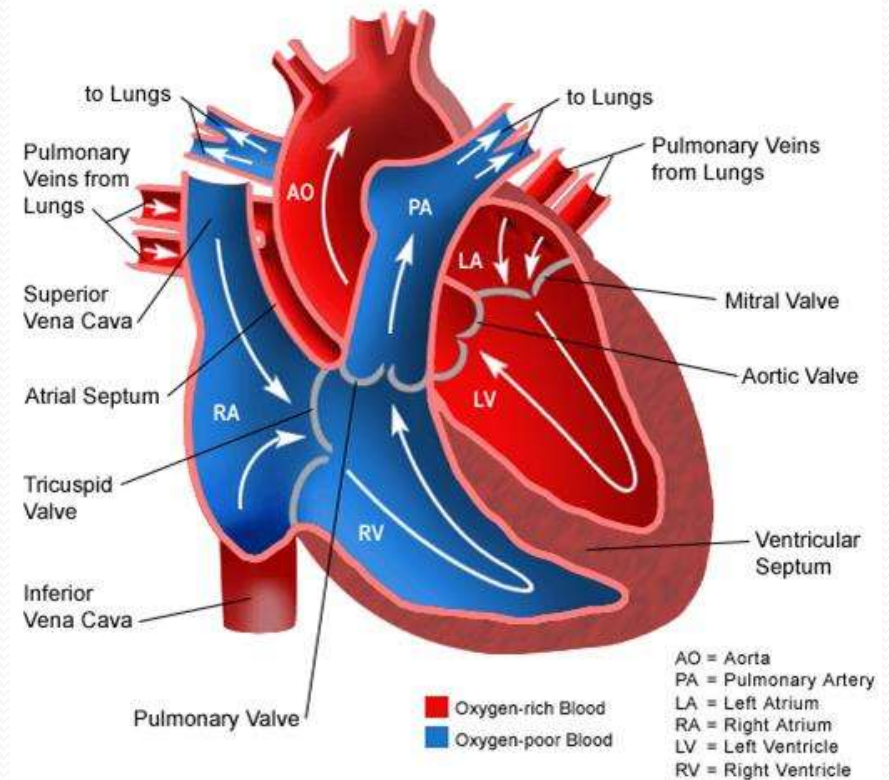


The Heart



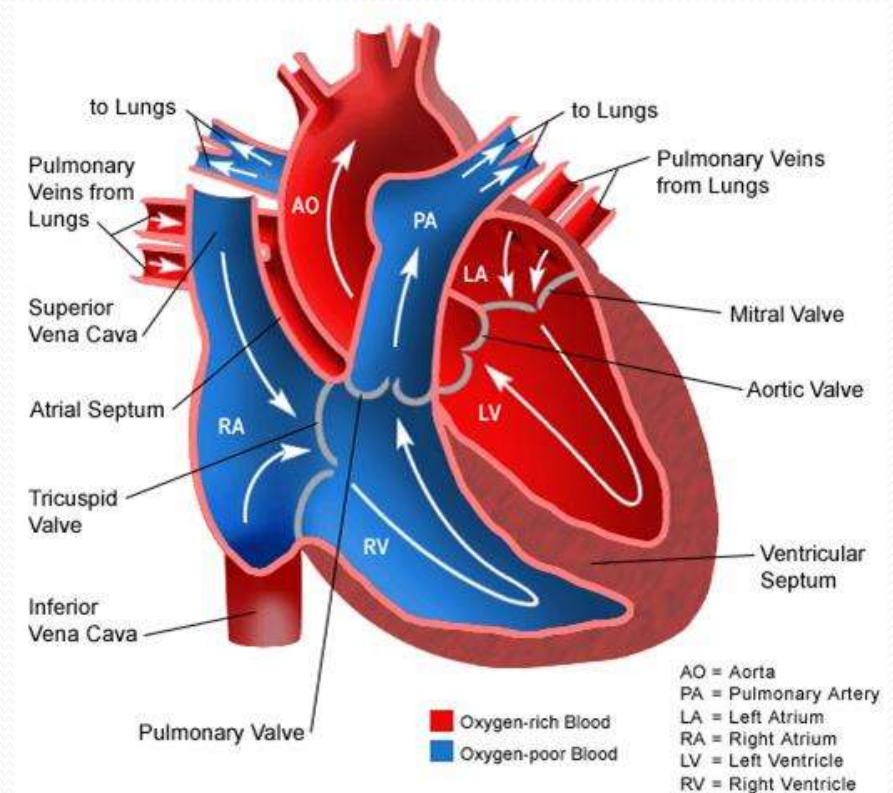
The Heart

- The human heart is approximately the size of a fist, and weighs less than a pound
- It is enclosed within the inferior mediastinum, the medial cavity of the thorax, and flanked on each side by the lungs



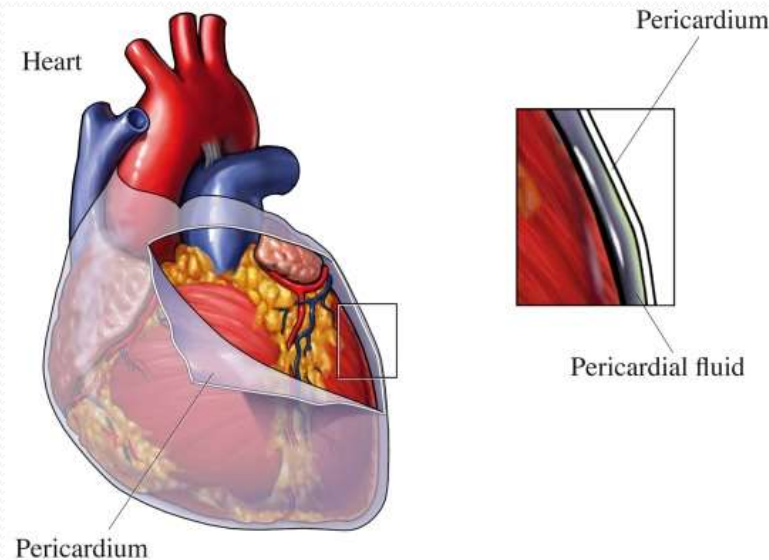
The Heart

- The pointed apex is directed toward the left hip and rests at about the fifth intercostal space
- The broad aspect, or base, points toward the right shoulder and lies beneath the second rib

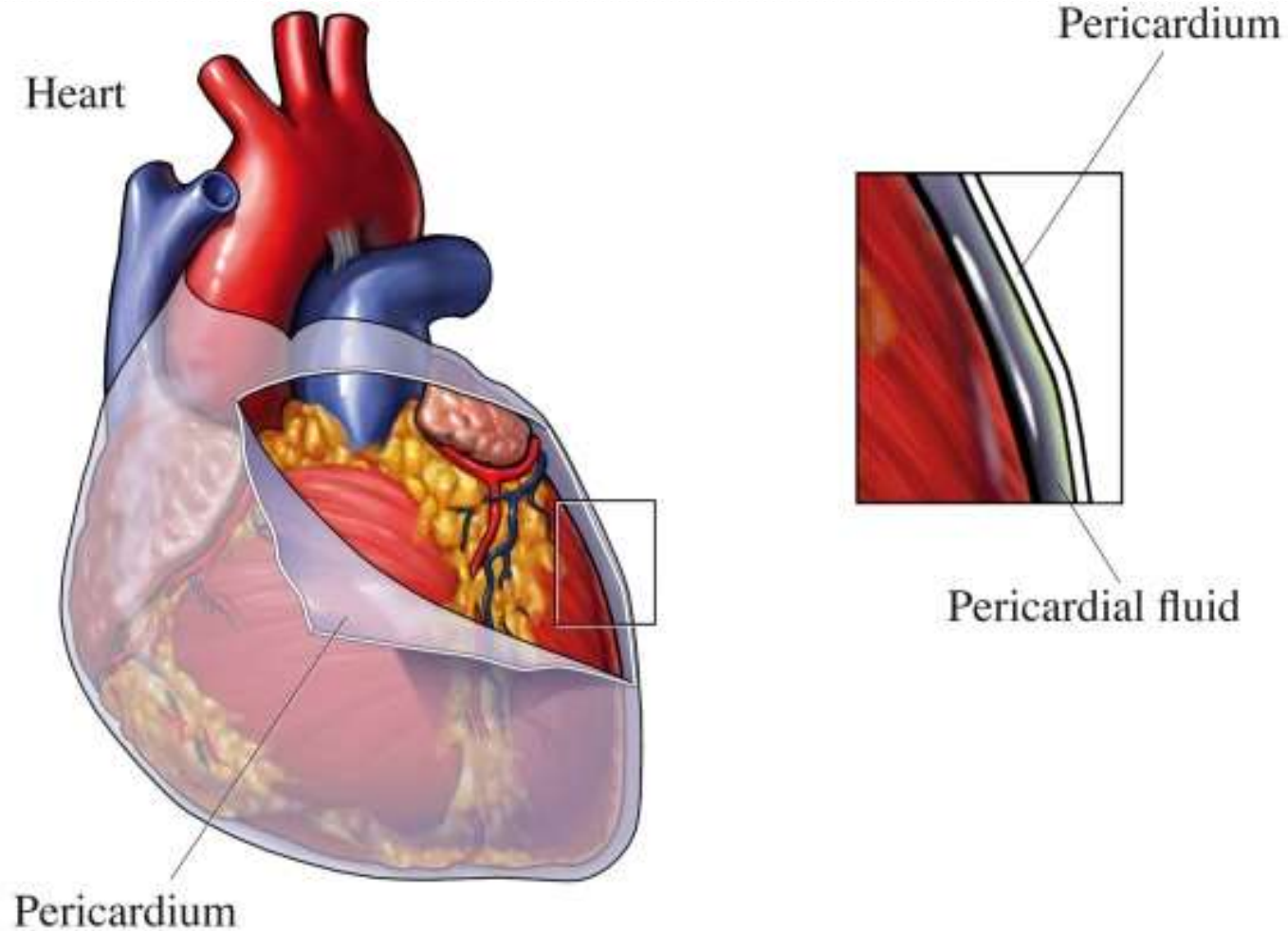


The Heart

- The heart is enclosed by a double-walled sac called the pericardium
- The superficial loosely fitted part is called the fibrous pericardium
 - Protects and anchors the heart

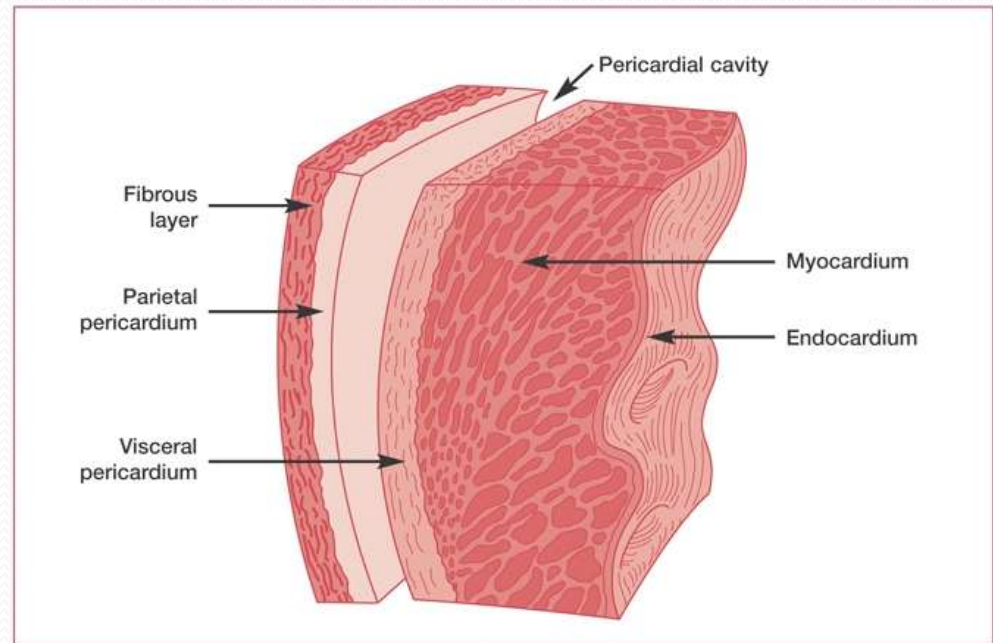


The Heart



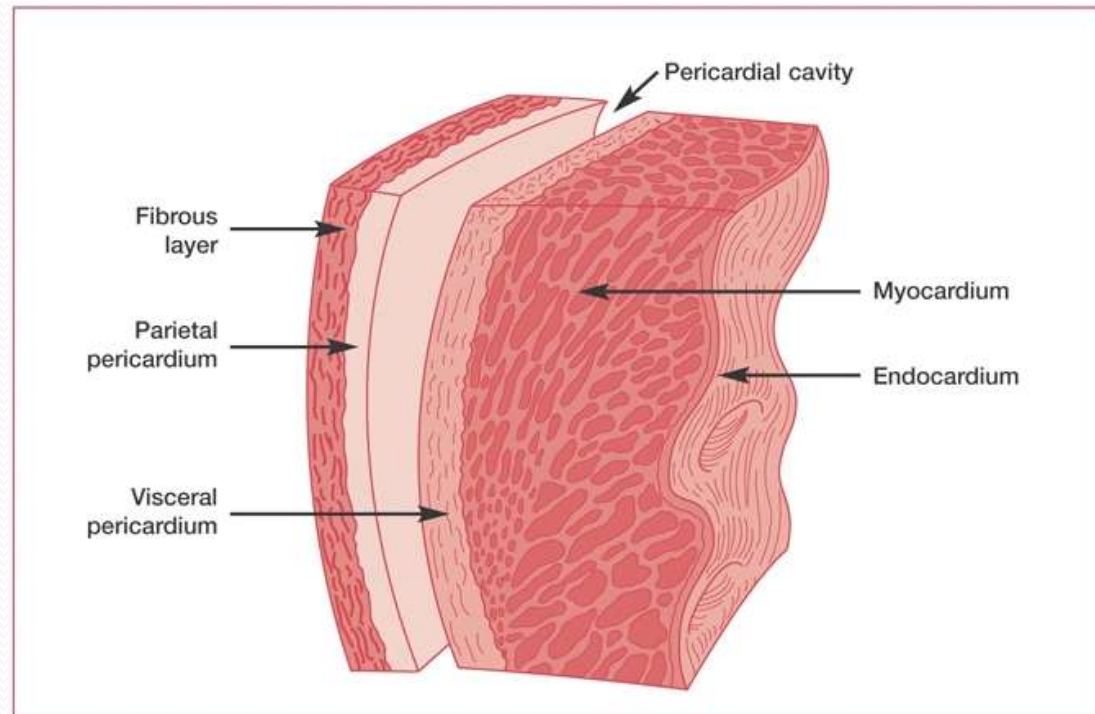
The Heart

- Deep to the fibrous pericardium is the slippery, two-layer serous pericardium
- The parietal layer lines the interior of the fibrous pericardium



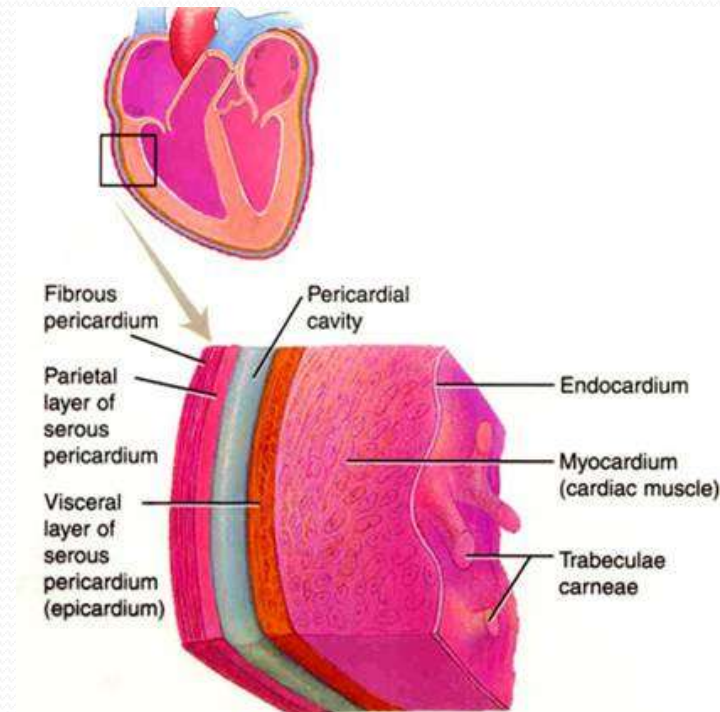
The Heart

- The parietal layer attaches to the large arteries leaving the heart and then makes a U-turn and continues inferiorly over the heart surface as the visceral layer, or epicardium



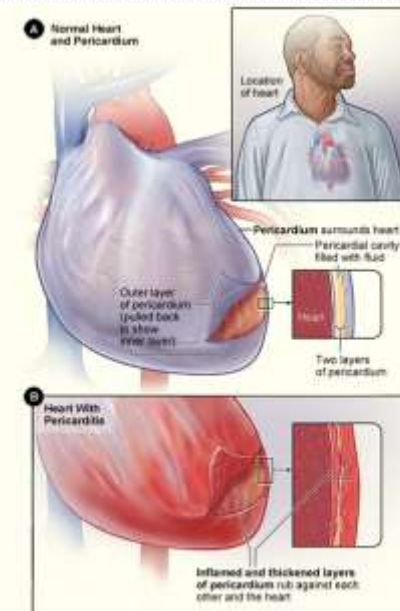
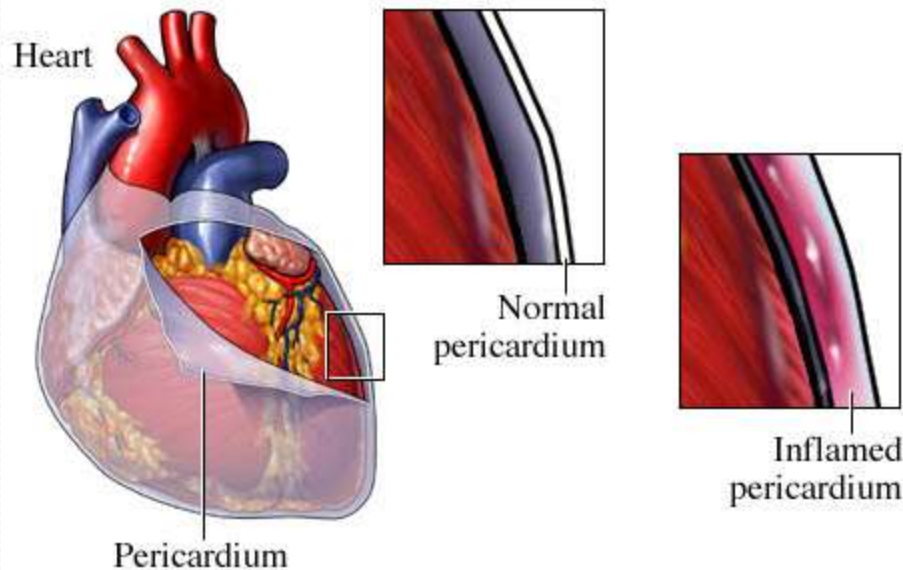
The Heart

- A slippery lubricating fluid is produced by the serous pericardial membranes which allows the heart to beat easily in a relative frictionless environment



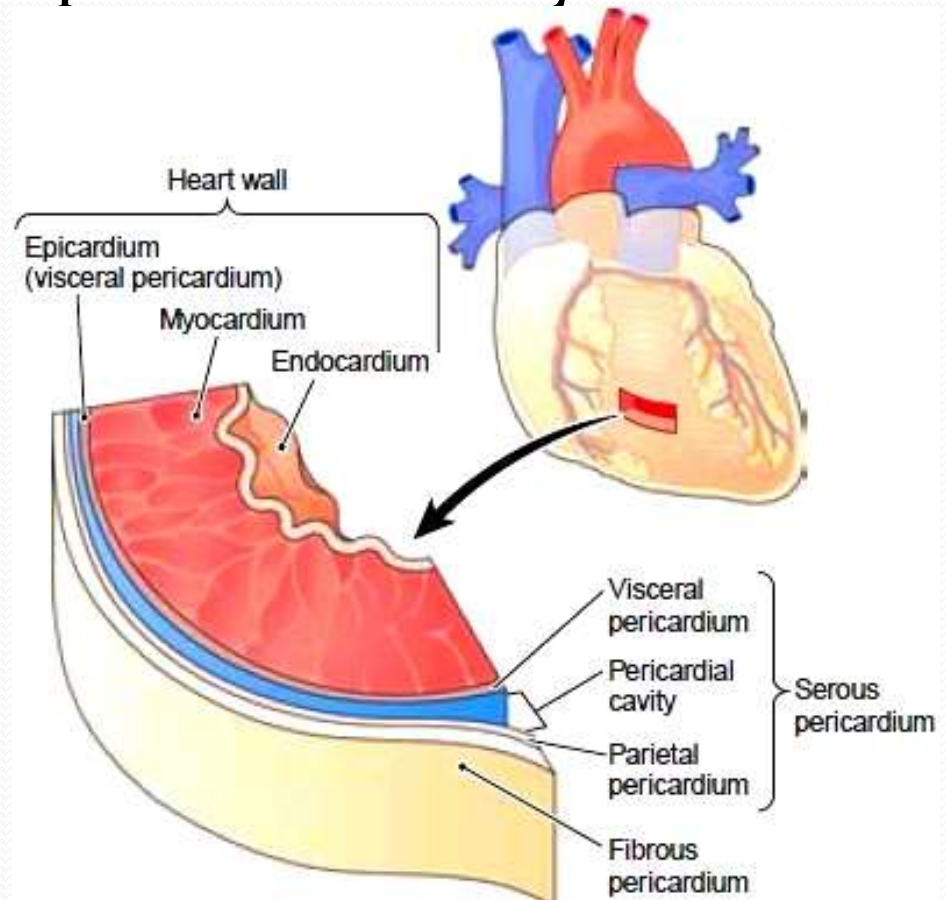
The Heart

- Inflammation of the pericardium, pericarditis, often results in a decrease in the serous fluid
- The cause the pericardial layers to stick, forming painful adhesions that interfere with heart movements



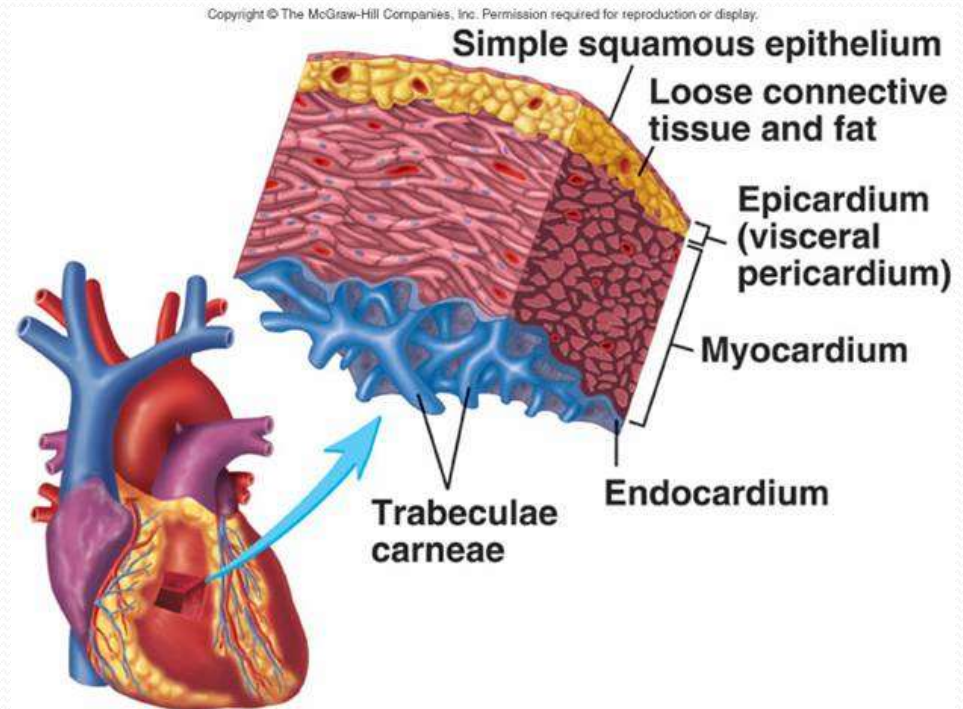
The Heart

- The heart walls are composed of three layers:
- 1. outer epicardium
- 2. myocardium
- 3. endocardium



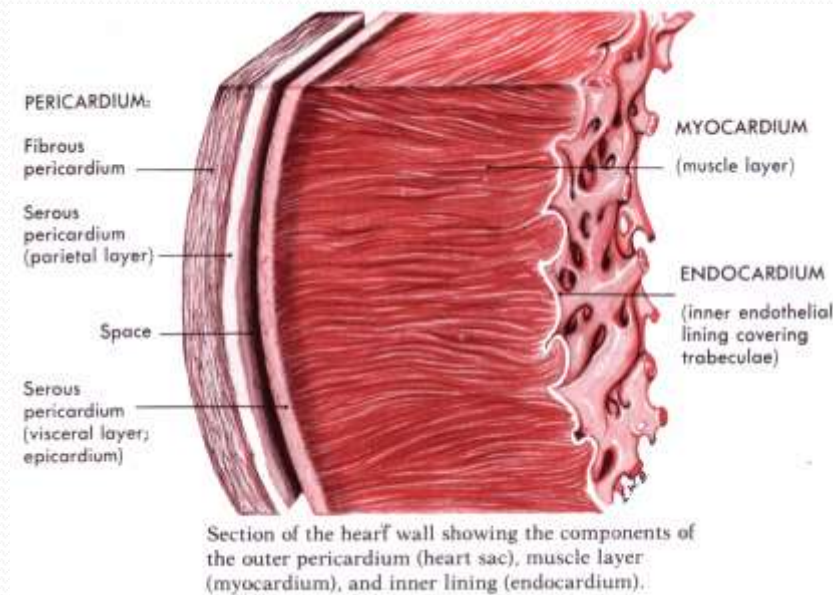
The Heart

- The myocardium consists of thick bundles of the cardiac muscle twisted into ringlike arrangements
- This is the layer of the heart that actually contracts
- Reinforced by dense, fibrous connective tissue (“heart skeleton”)



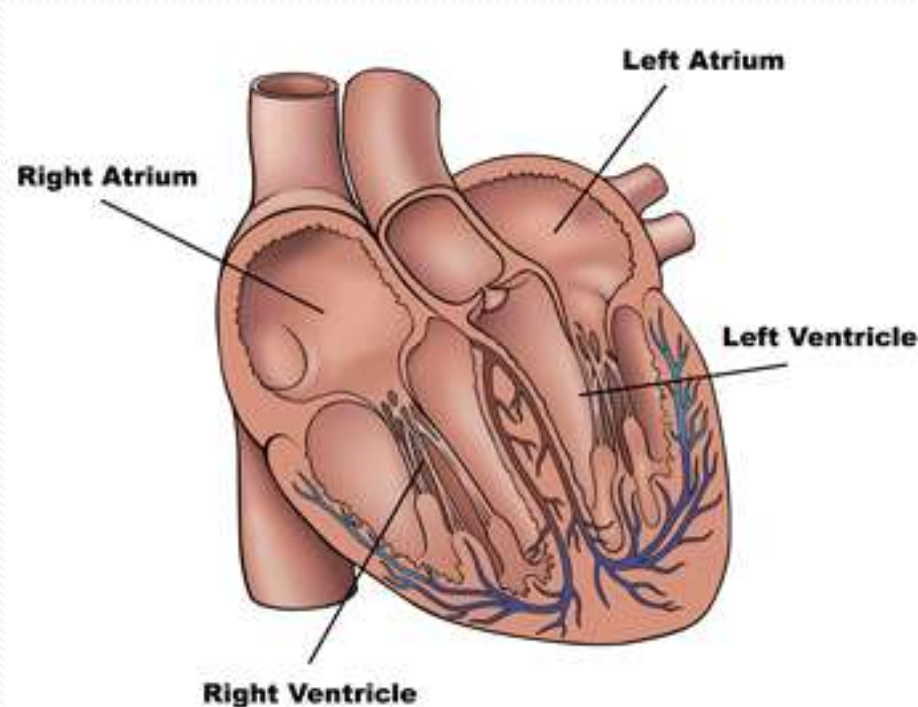
The Heart

- The endocardium is a thin, glistening sheet of endothelium that lines the heart chambers
- Continuous with the linings of the blood vessels leaving and entering the heart



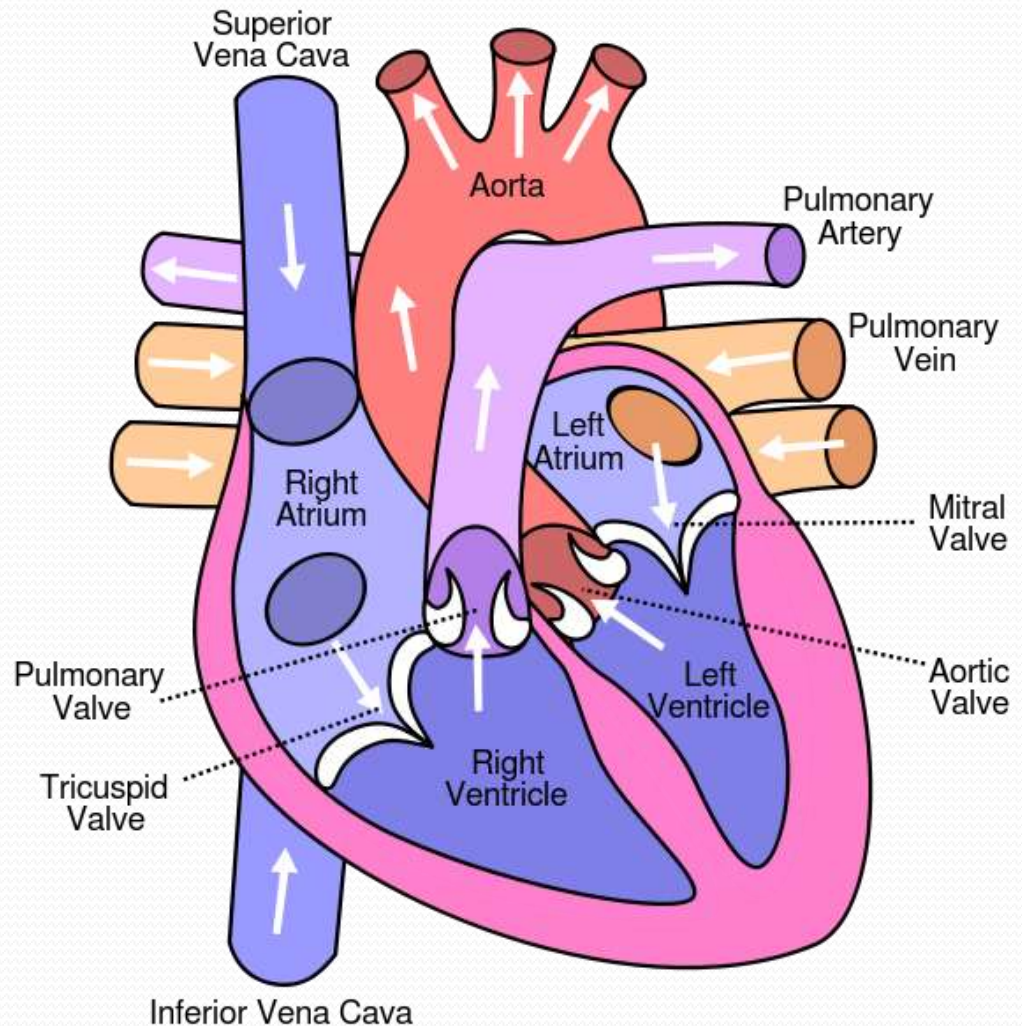
The Heart

- The heart has four hollow chambers:
- 2 atria – receiving chambers
- 2 ventricles – filling chambers

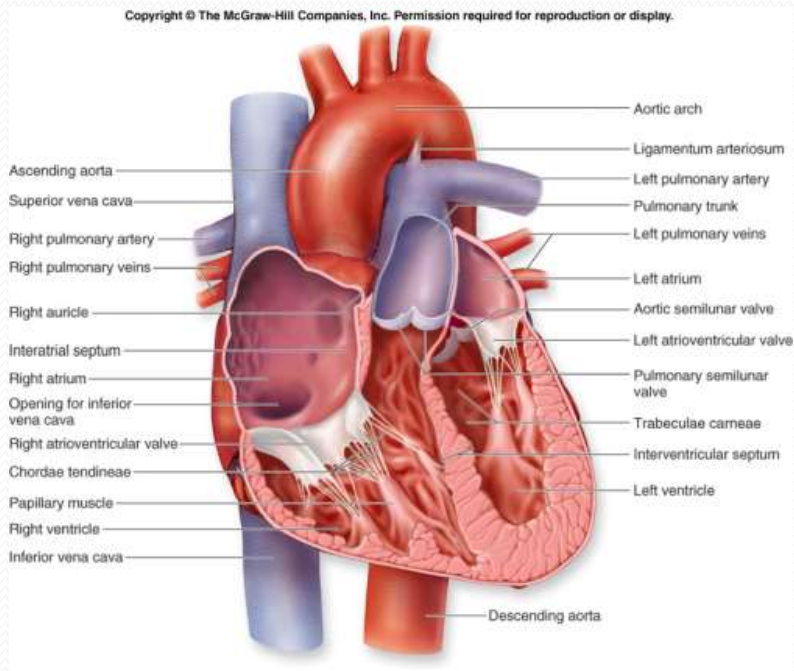


The Heart

- Blood flows into the atria under low pressure from the veins, and continues into the ventricles



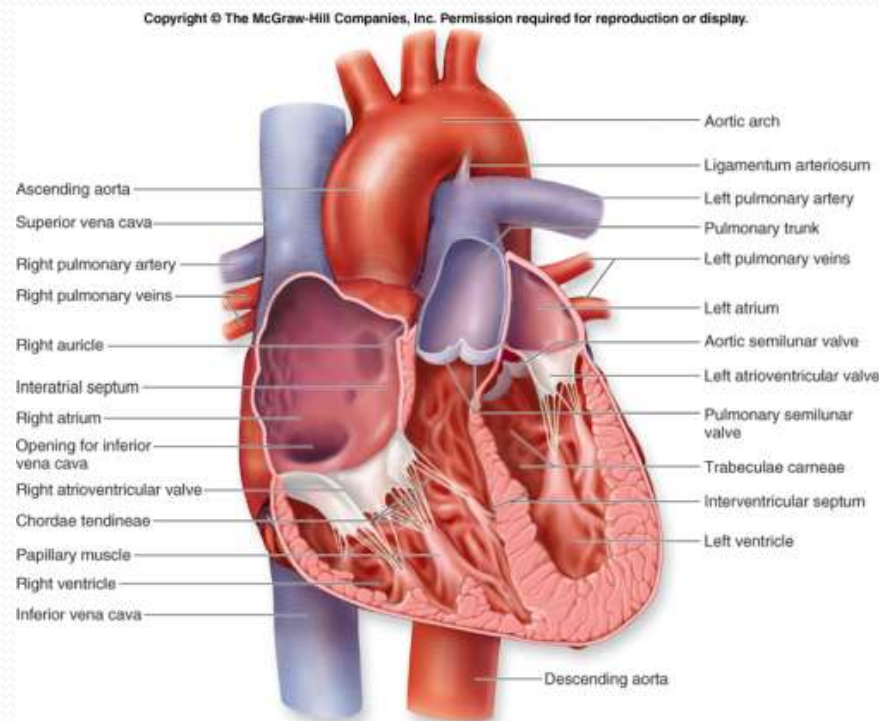
The Heart



- The ventricles are thick-walled discharging chambers
- They are the pumps of the heart
- When they contract, blood is propelled out of the heart and into circulation

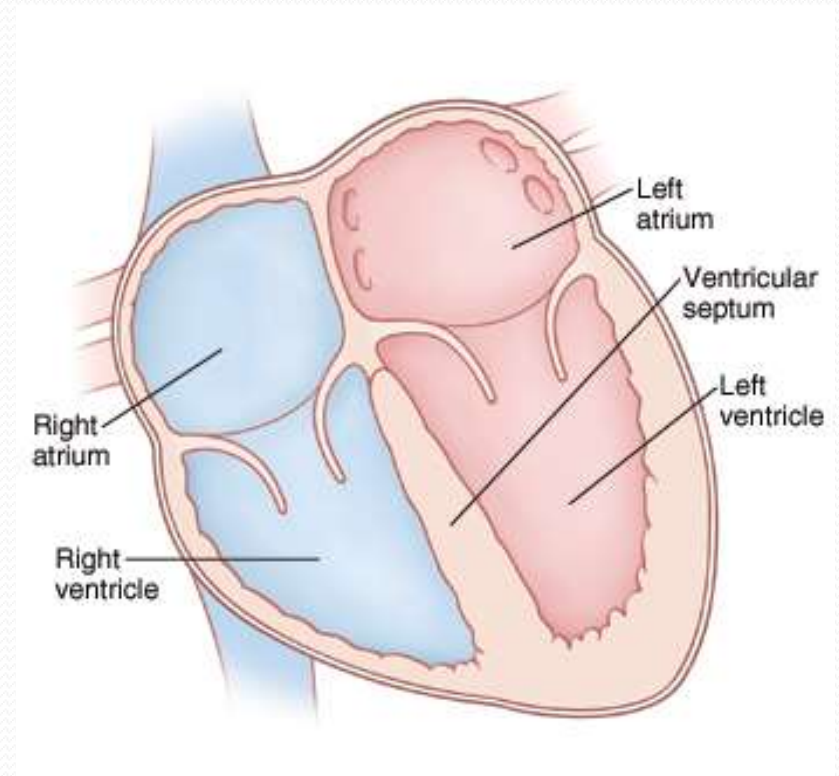
The Heart

- The right ventricle forms most of the heart's anterior surface
- The left ventricle forms the apex



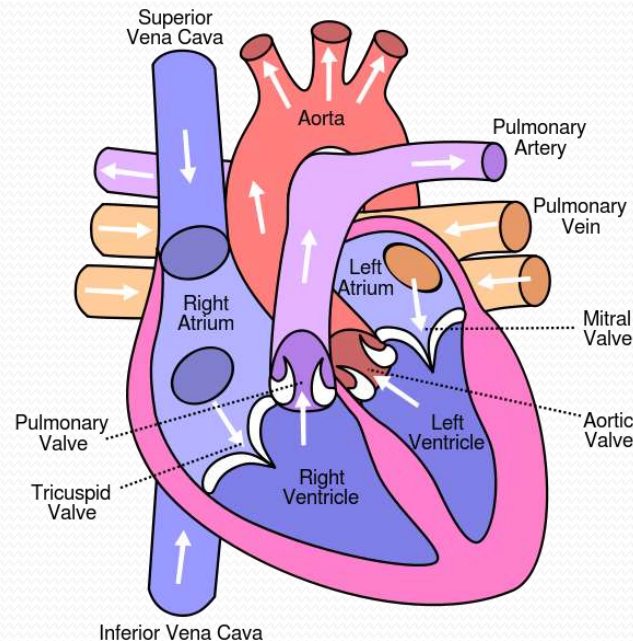
The Heart

- The septum that divides the heart longitudinally is the interventricular septum or the interatrial septum based on the chambers it separates

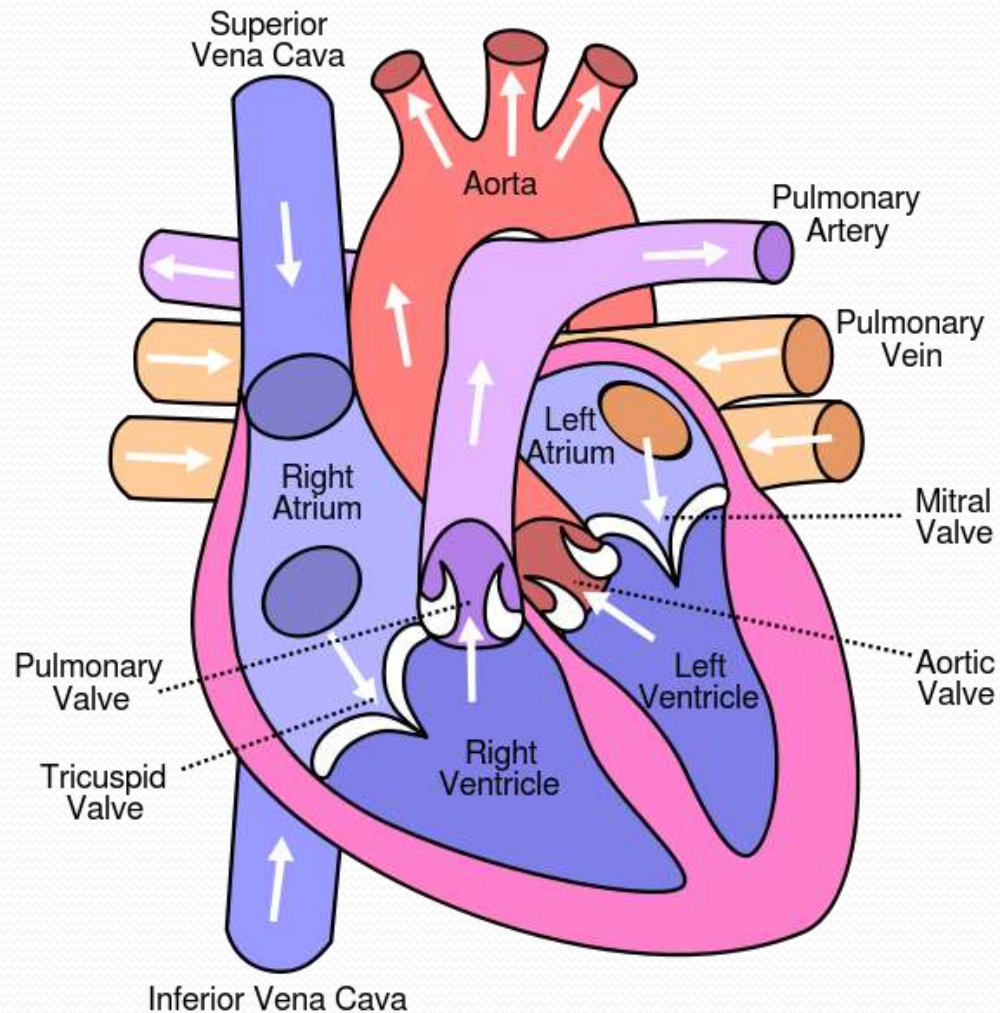


The Heart

- The heart functions as a double pump
- The right side works as the pulmonary circuit pump
- Receives relatively oxygen-poor blood from the veins of the body through the large superior and inferior vena cavae

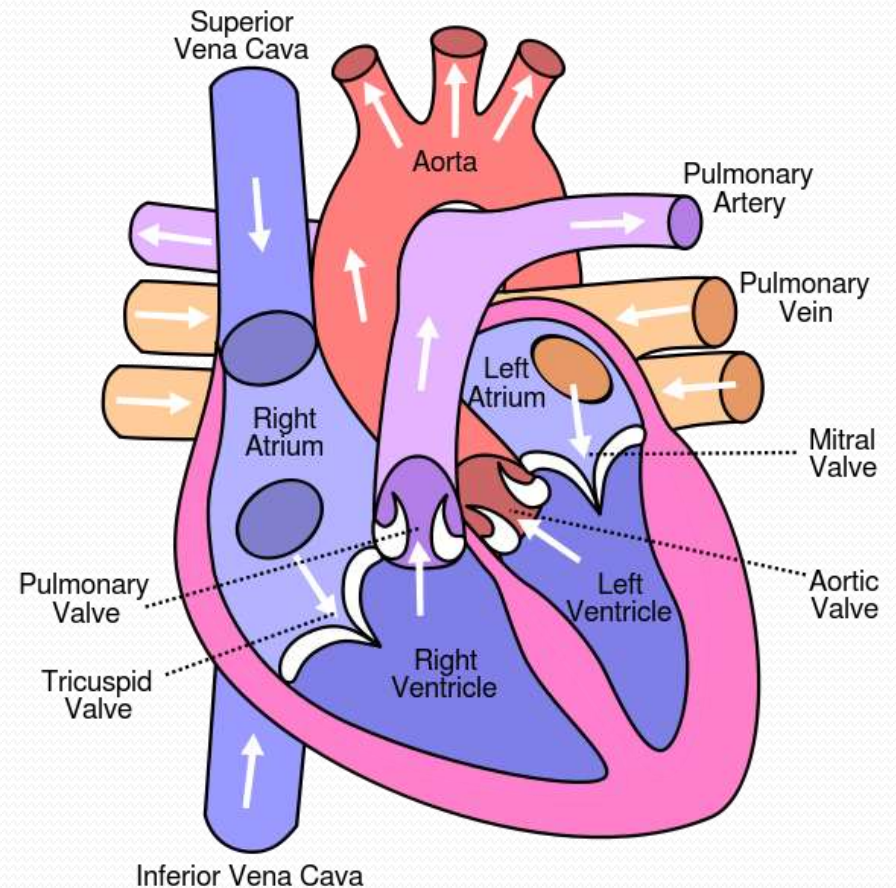


The Heart



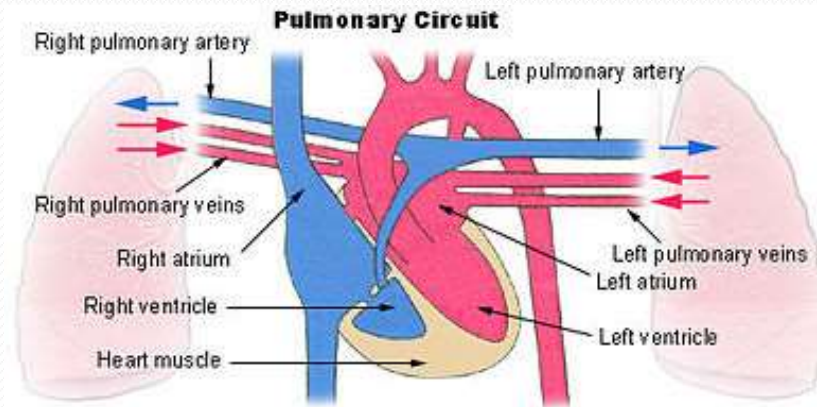
The Heart

- The blood then pumps out through the pulmonary trunk which splits into the left and right pulmonary arteries
- The pulmonary arteries carry blood to the lungs, where oxygen is picked up and carbon dioxide is unloaded

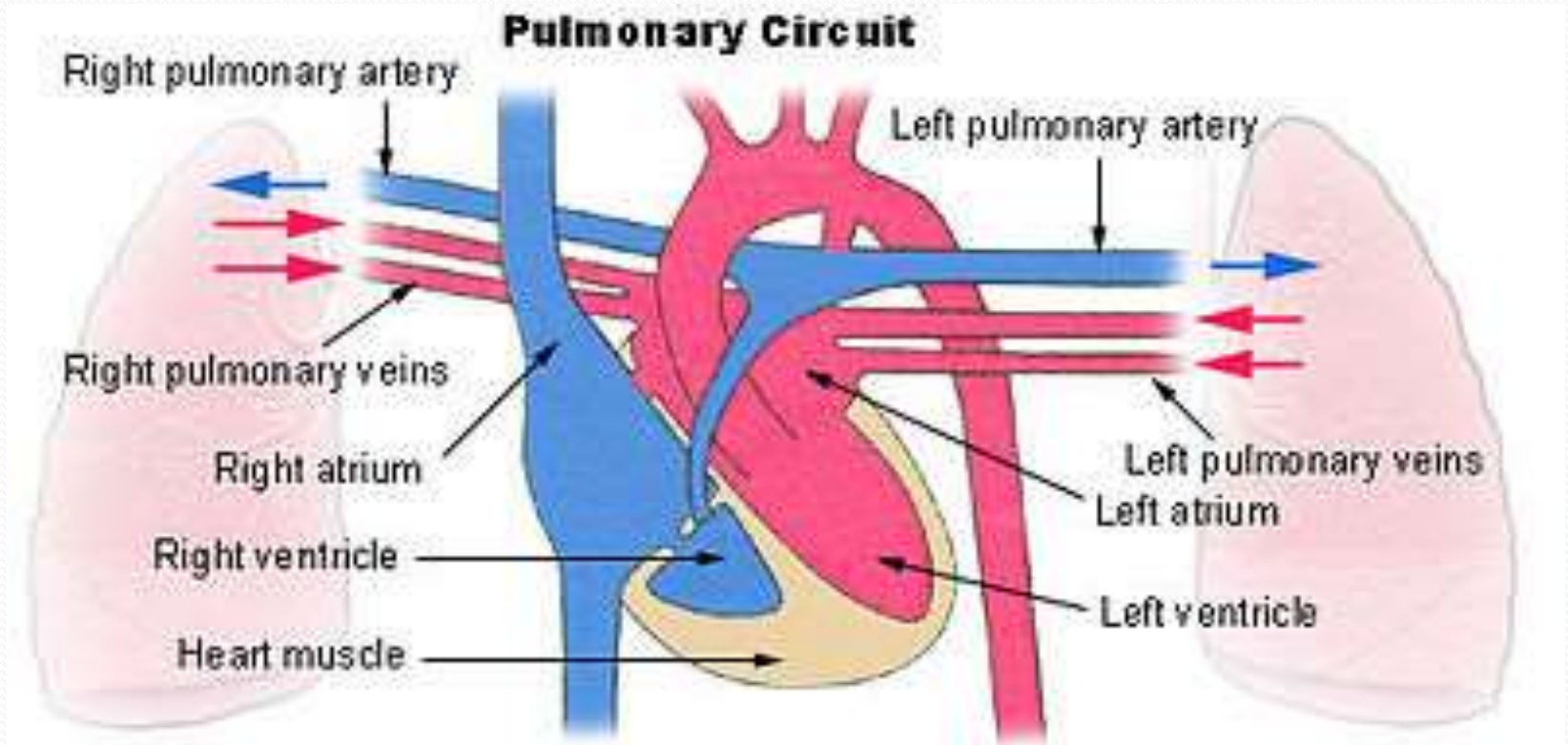


The Heart

- Oxygen-rich blood drains from the lungs and is returned to the left side of the heart through the four pulmonary veins
- This circuit is call pulmonary circulation
- Its only function is to carry blood to the lungs for gas exchange and then return it to the heart

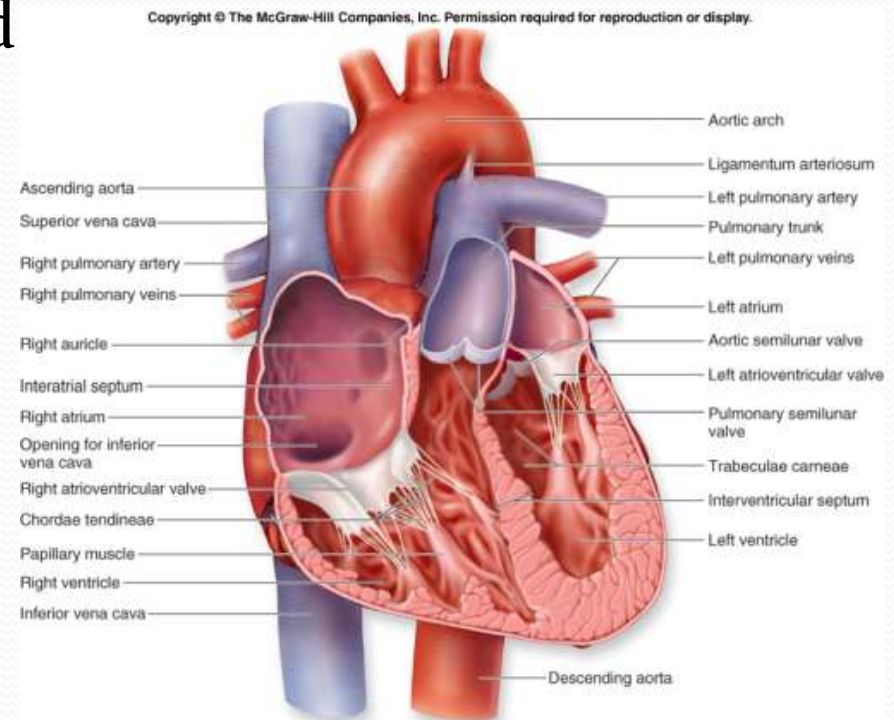


The Heart



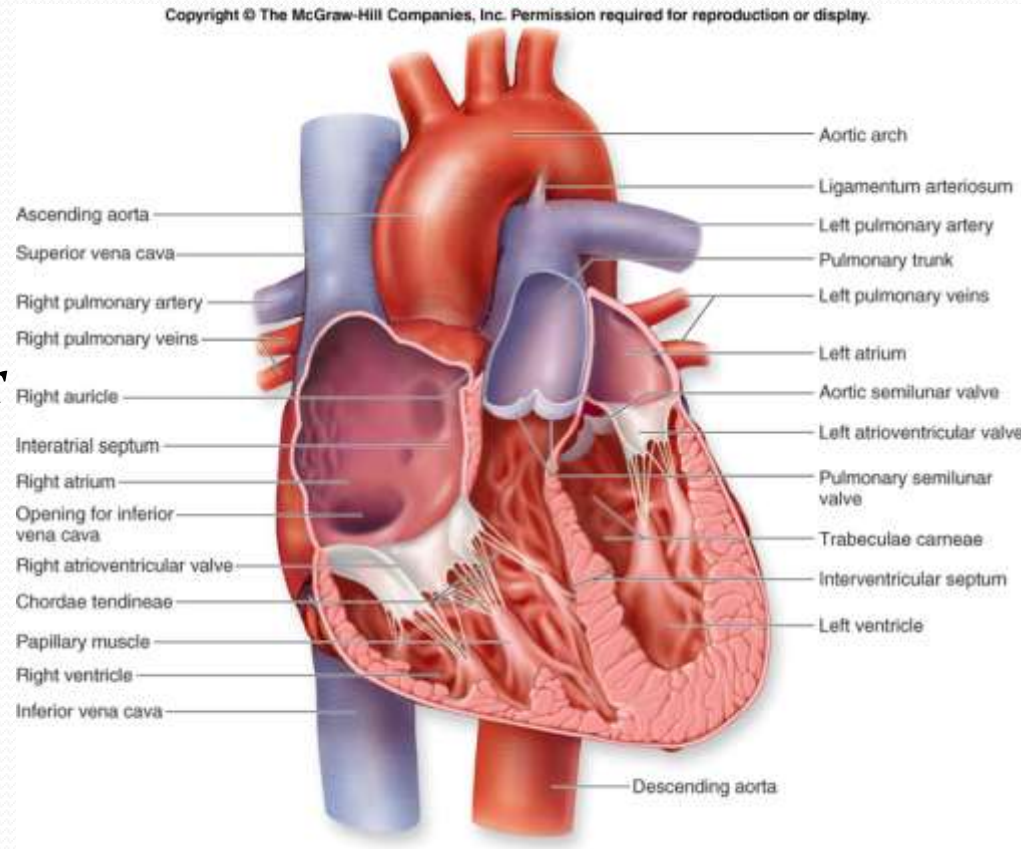
The Heart

- Blood returned to the left side of the heart is pumped out of the heart into the aorta
- The systemic arteries branch from the aorta to supply the body tissues with blood



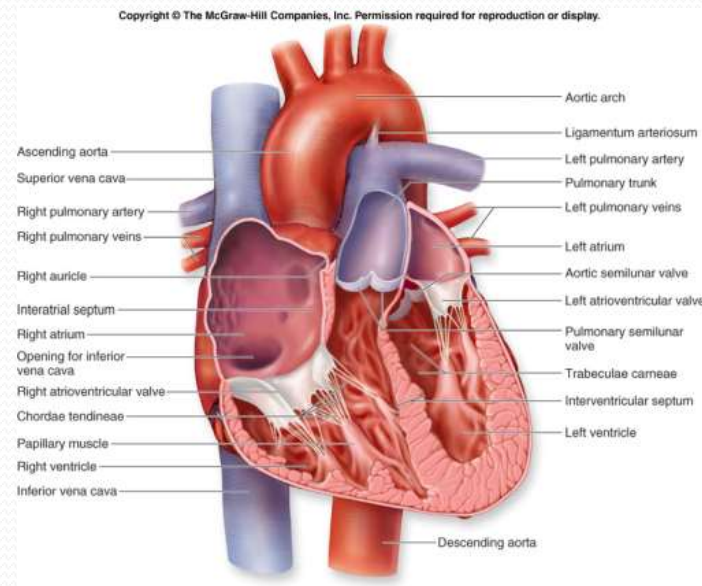
The Heart

- Oxygen-poor blood circulates from the tissues back to the right atrium via the systemic veins, which empty their blood into either the superior or inferior vena cava



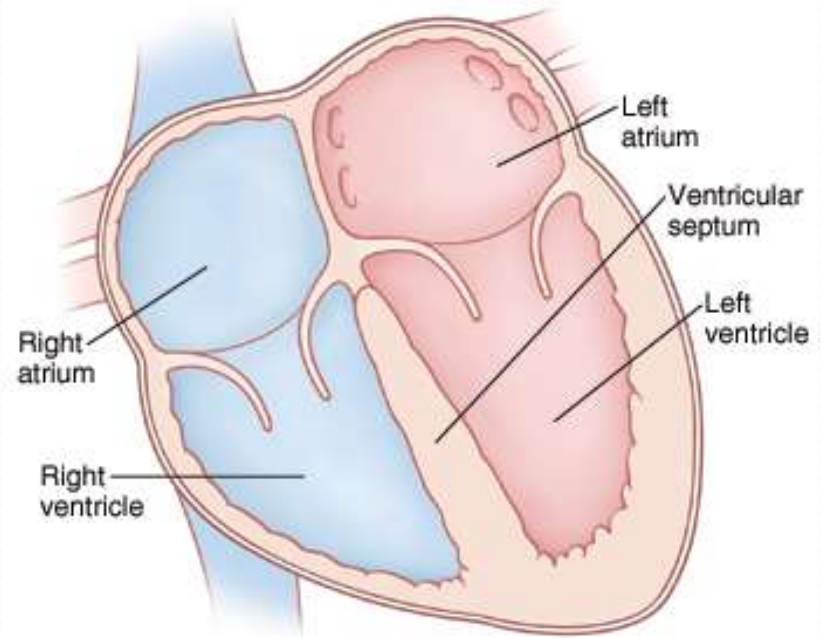
The Heart

- This second circuit, from the left side of the heart through the body tissues and back to the right side of the heart is called systemic circulation
- It supplies oxygen and nutrient-rich blood to all body organs

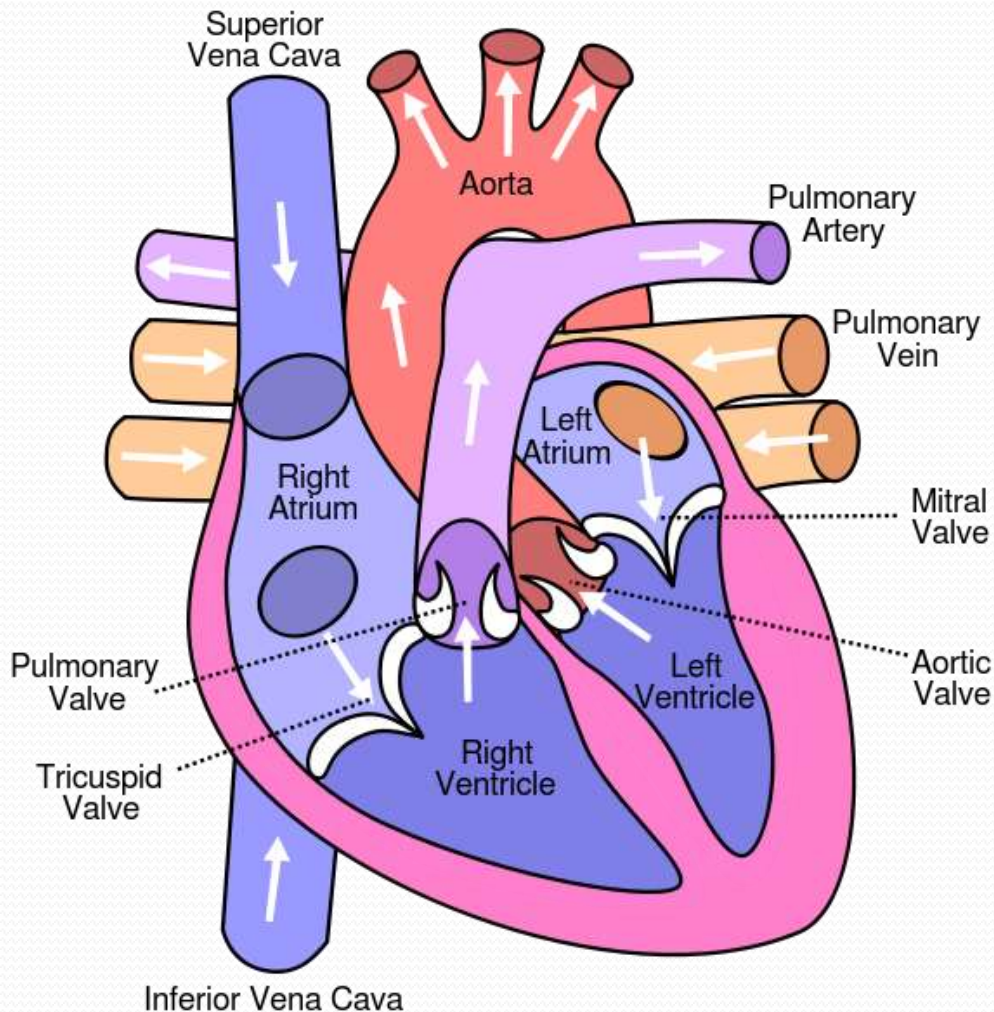


The Heart

- Because the left ventricle is the systemic pump that pumps blood over a much longer pathway through the body, its walls are thicker than those of the right ventricle
- It is a more powerful pump



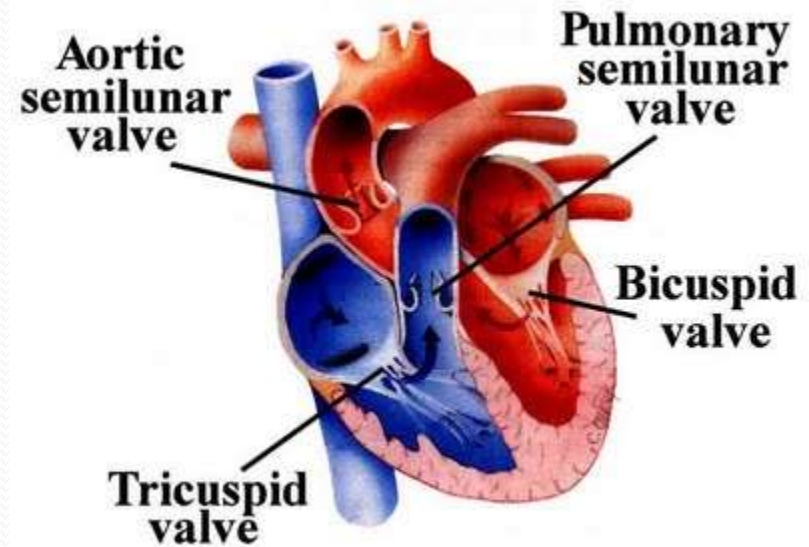
The Heart



- The heart also has four valves:
- 2 that separate the atria from the ventricles
- 2 that separate the ventricles from their arteries
- All of these valves prevent back flow

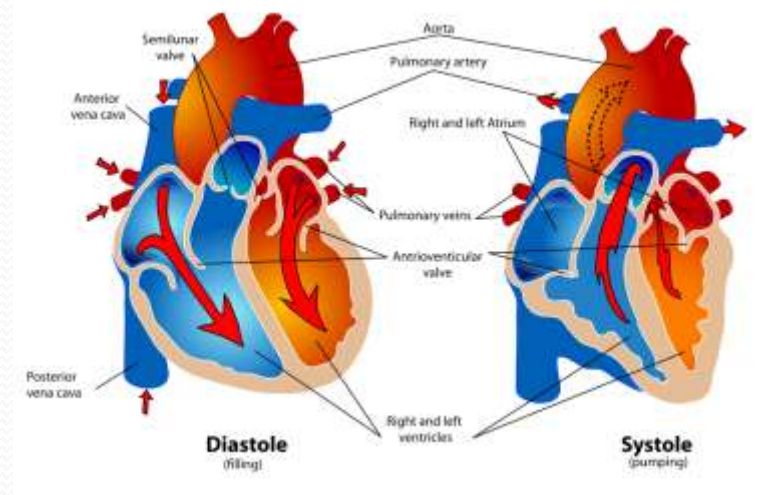
The Heart

- The atrioventricular (AV) valves are between the atria and ventricles
- On the left is the bicuspid or mitral valve
- On the right is the tricuspid valve
- They are all anchored by the chordae tendineae



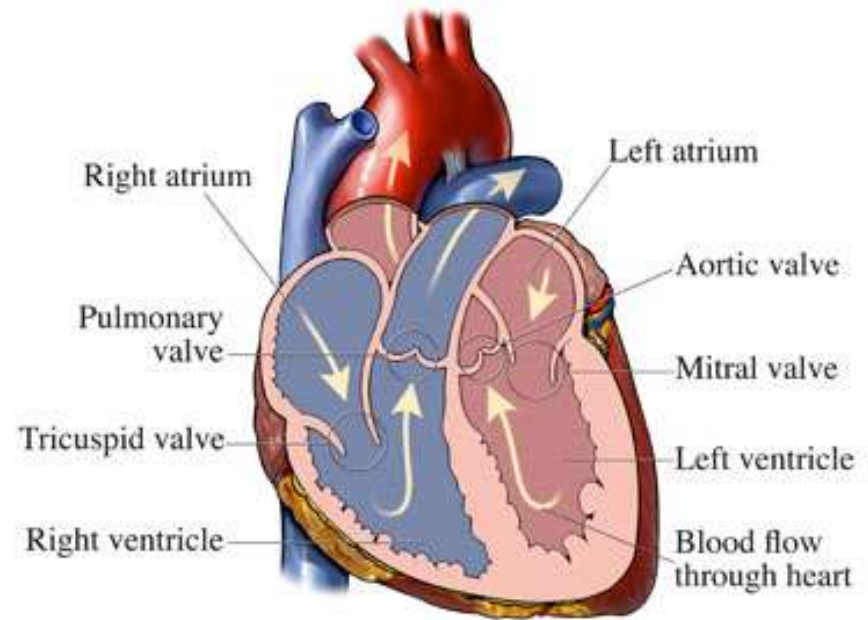
The Heart

- When the heart is relaxed and blood is passively filling its chambers, the AV-valve flaps hang limply into the ventricles
- As the ventricles contract, they press on the blood in their chamber, and the intraventricular pressure rises



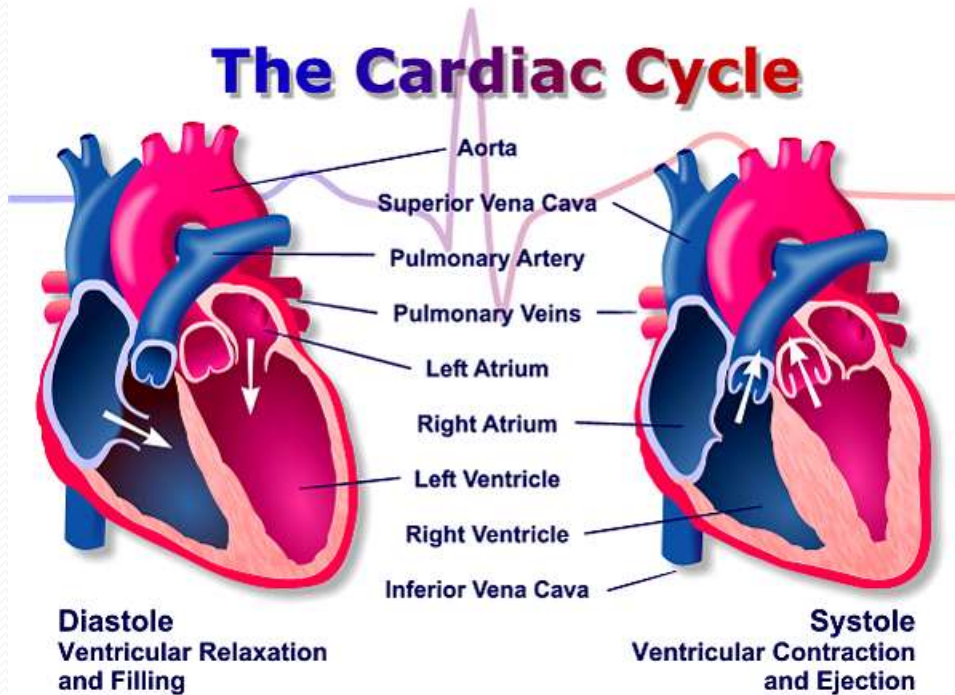
The Heart

- The semilunar valves guard the bases of the large arteries leaving the ventricular chambers
- On the right is the pulmonary valve
- On the left is the aortic valve



The Heart

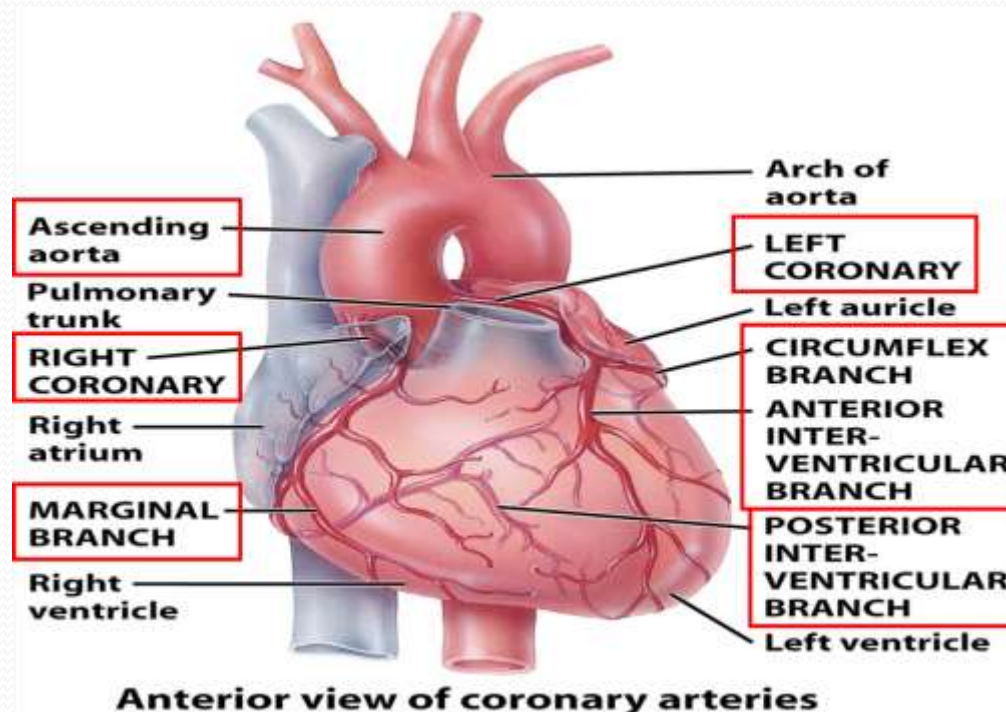
The Cardiac Cycle



- When the ventricles are contracting these valves are forced open and flattened against the arterial walls
- When the ventricles are relaxed the blood flows back towards the heart
- This prevents arterial blood from reentering the heart

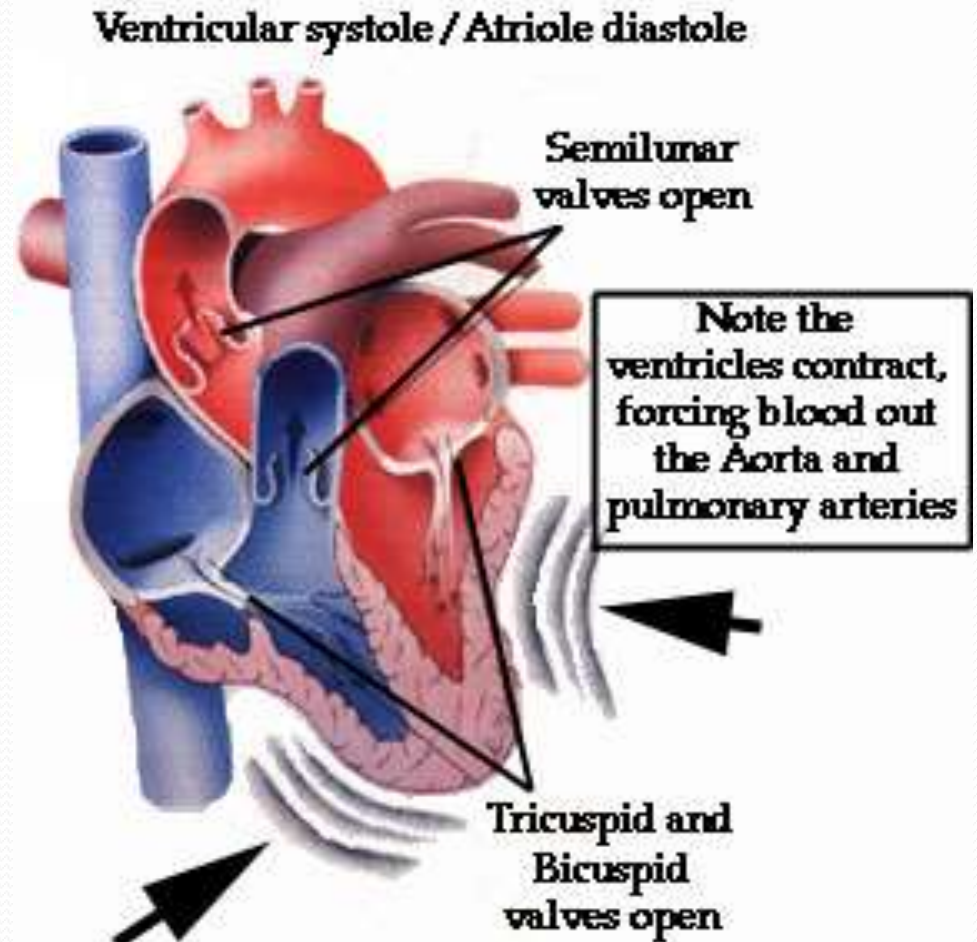
The Heart

- The coronary arteries branch from the base of the aorta and encircle the heart in the coronary sulcus (AV groove) at the junction of the atria and ventricles



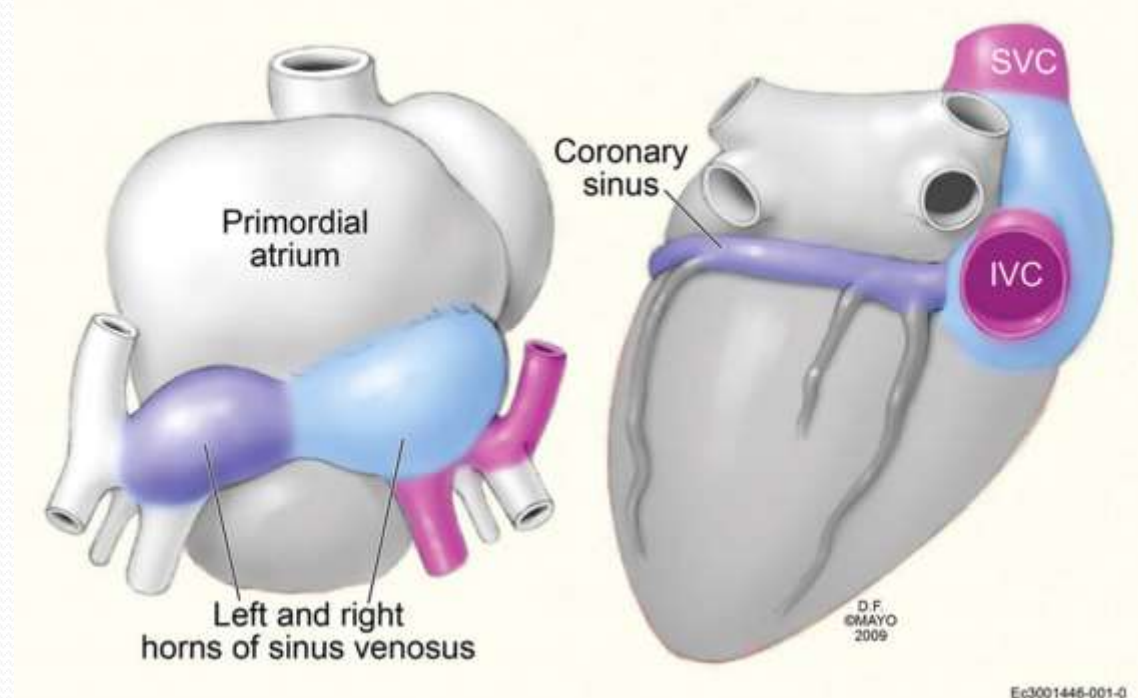
The Heart

- The coronary arteries and their major branches are compressed when the ventricles are contracting and fill when the heart is relaxed



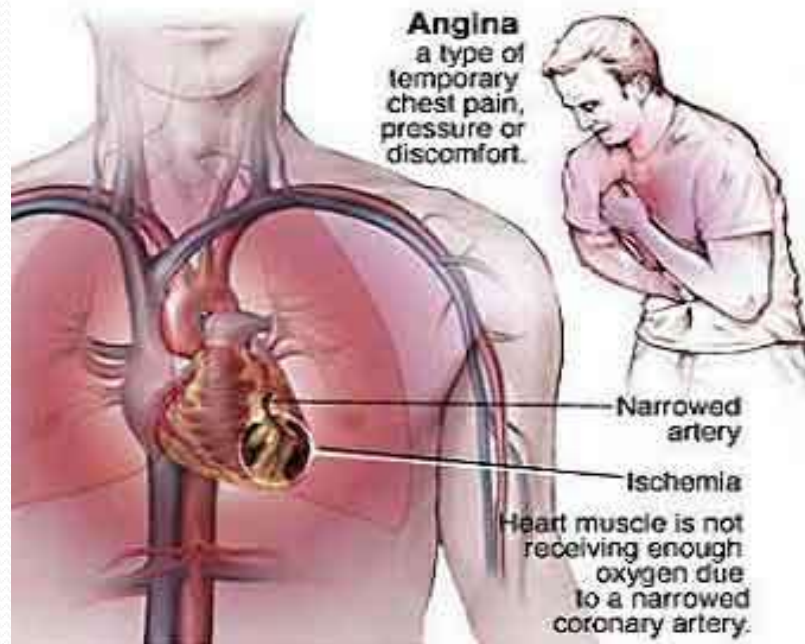
The Heart

- The myocardium is drained by several cardiac veins, which empty into the coronary sinus
- The coronary sinus, in turn, empties into the right atrium



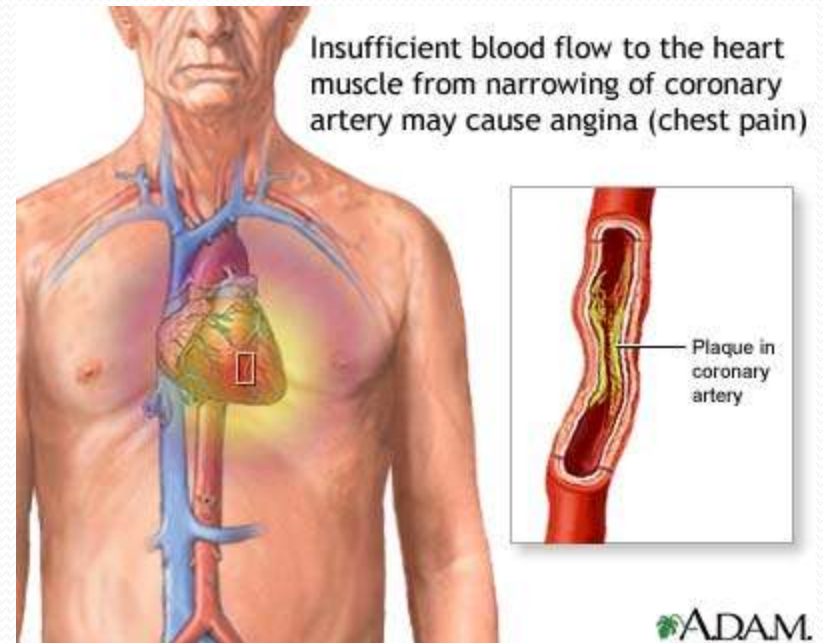
The Heart

- When the heart beats rapidly the myocardium can receive an inadequate amount of blood
- This can result in crushing chest pain called angina pectoris

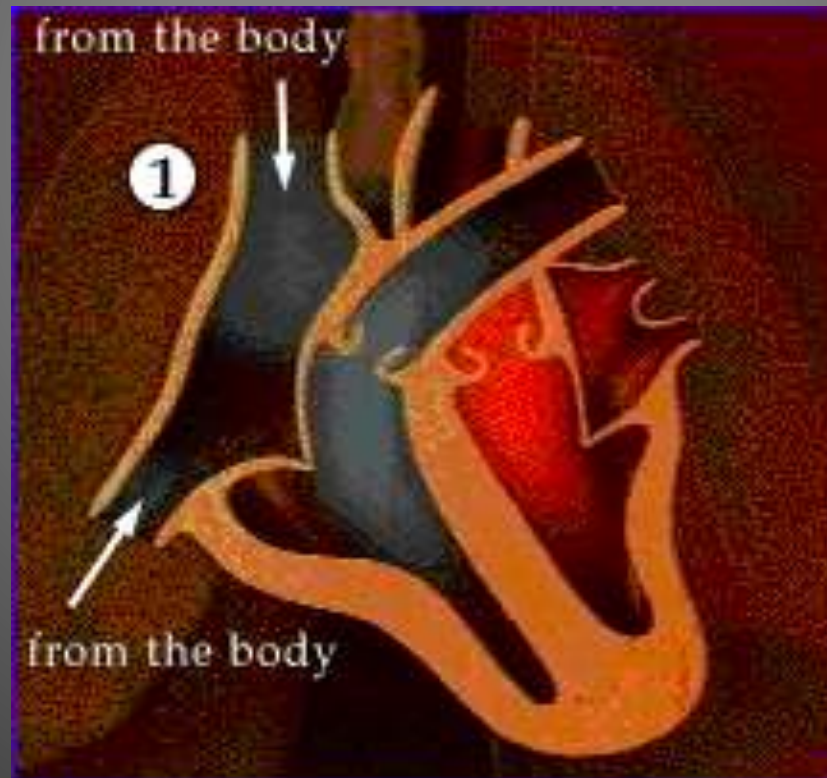


The Heart

- Pain due to angina pectoris is a warning sign
- If angina is prolonged, oxygen-deprived heart cells may die forming an infarct
- The resulting myocardial infarction is a “heart attack”

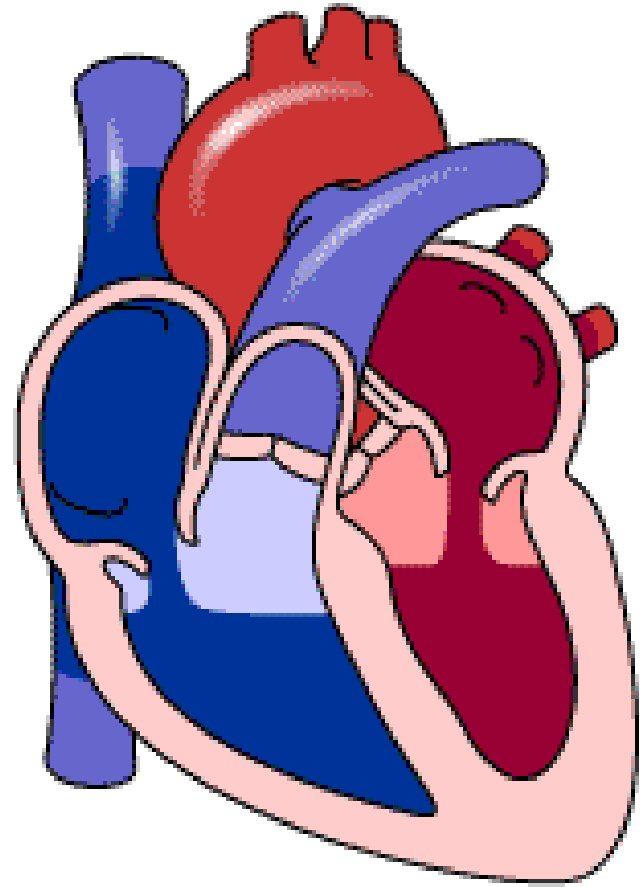


Heart Physiology

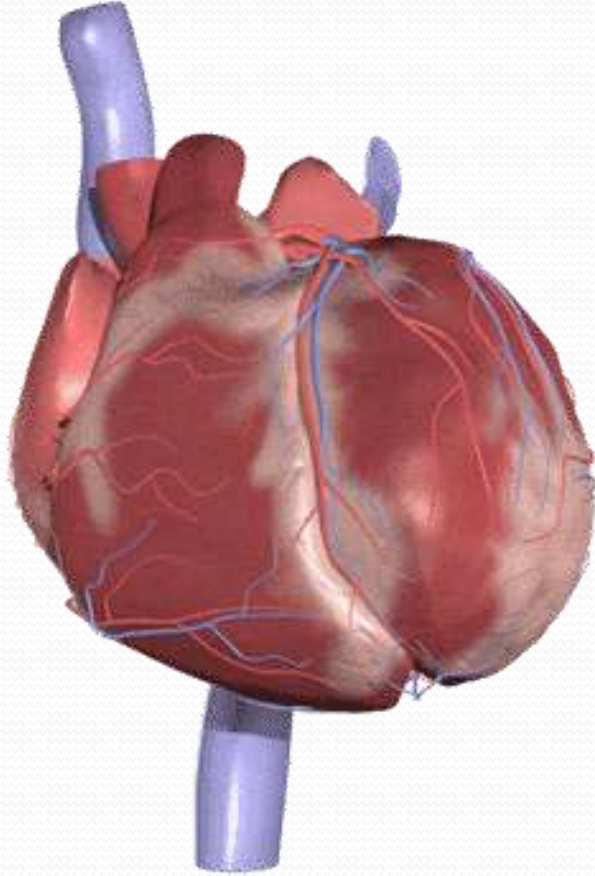


Heart Physiology

- The heart pumps the body's 6 quart supply of blood through the blood vessels over 1000 times per day
- In reality, the heart pumps about 6000 quarts of blood in a single day



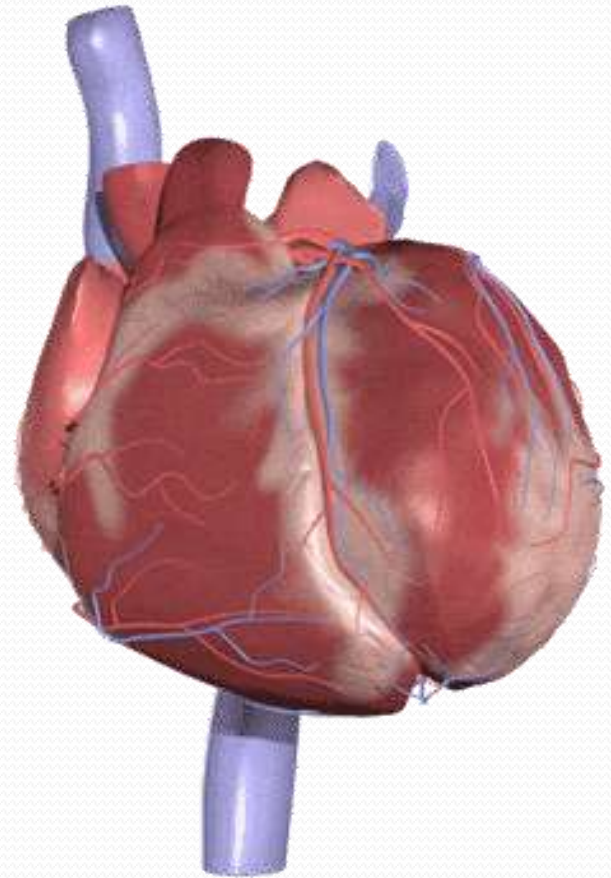
Heart Physiology



- Cardiac muscles cells can and do contract spontaneously and independently, even if all nervous connections are severed
- These contractions occur in a regular and continuous way

Heart Physiology

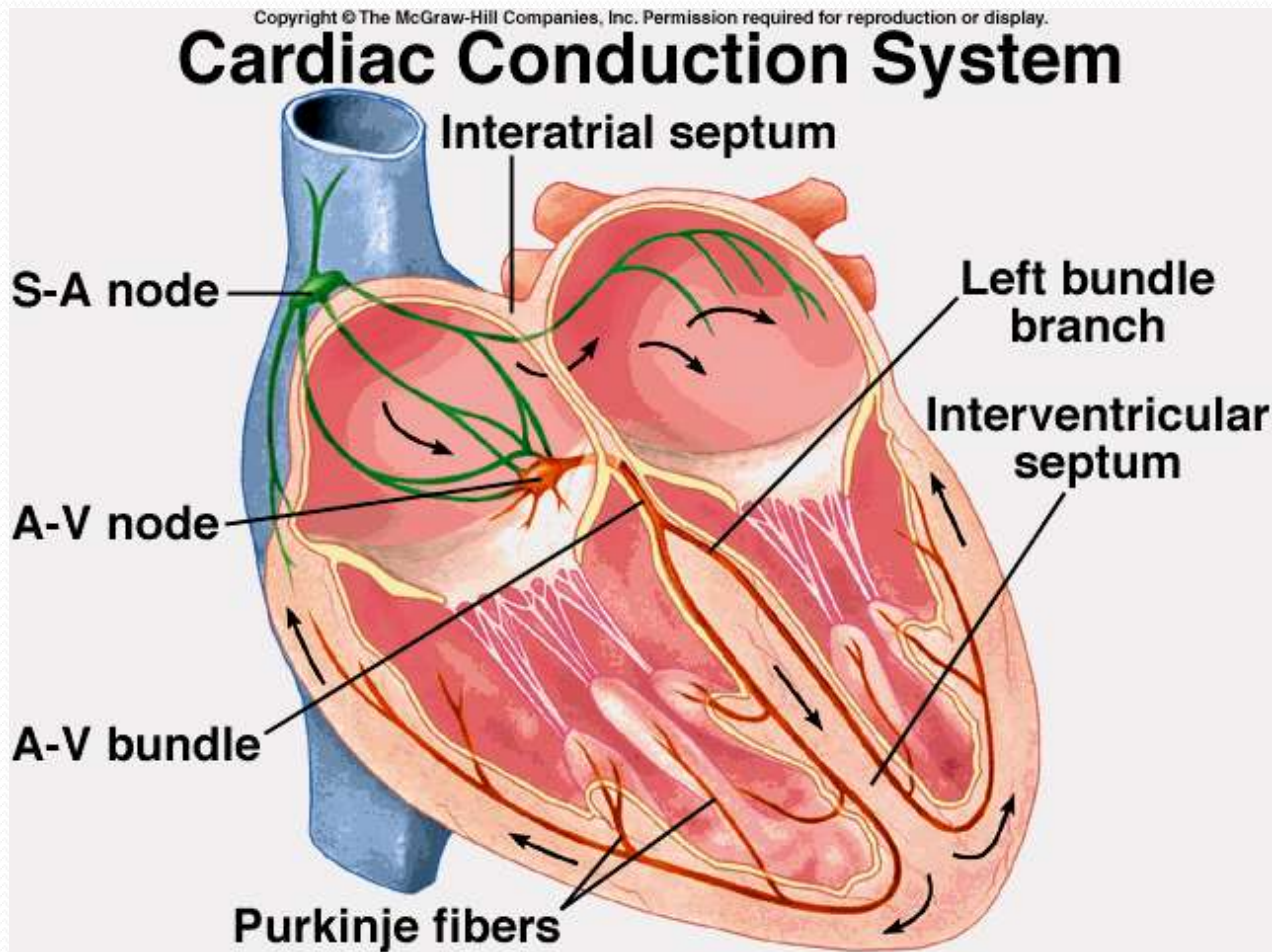
- Although cardiac muscle can beat independently, the muscle cells on different areas of the heart have different rhythms
- Atrial cells – 60 bpm
- Ventricular cells – 20-40 bpm



Heart Physiology

- Two systems act to regulate heart activity:
- 1. Autonomic nervous system – brakes and accelerator
 - Acts to decrease or increase heart rate
- 2. Intrinsic conduction system (nodal system)
 - Composed of specialized tissue that is a cross between muscle and nervous tissue
 - Causes heart muscle depolarization from the atria to the ventricles
 - Enforces contraction rate ~ 75bpm

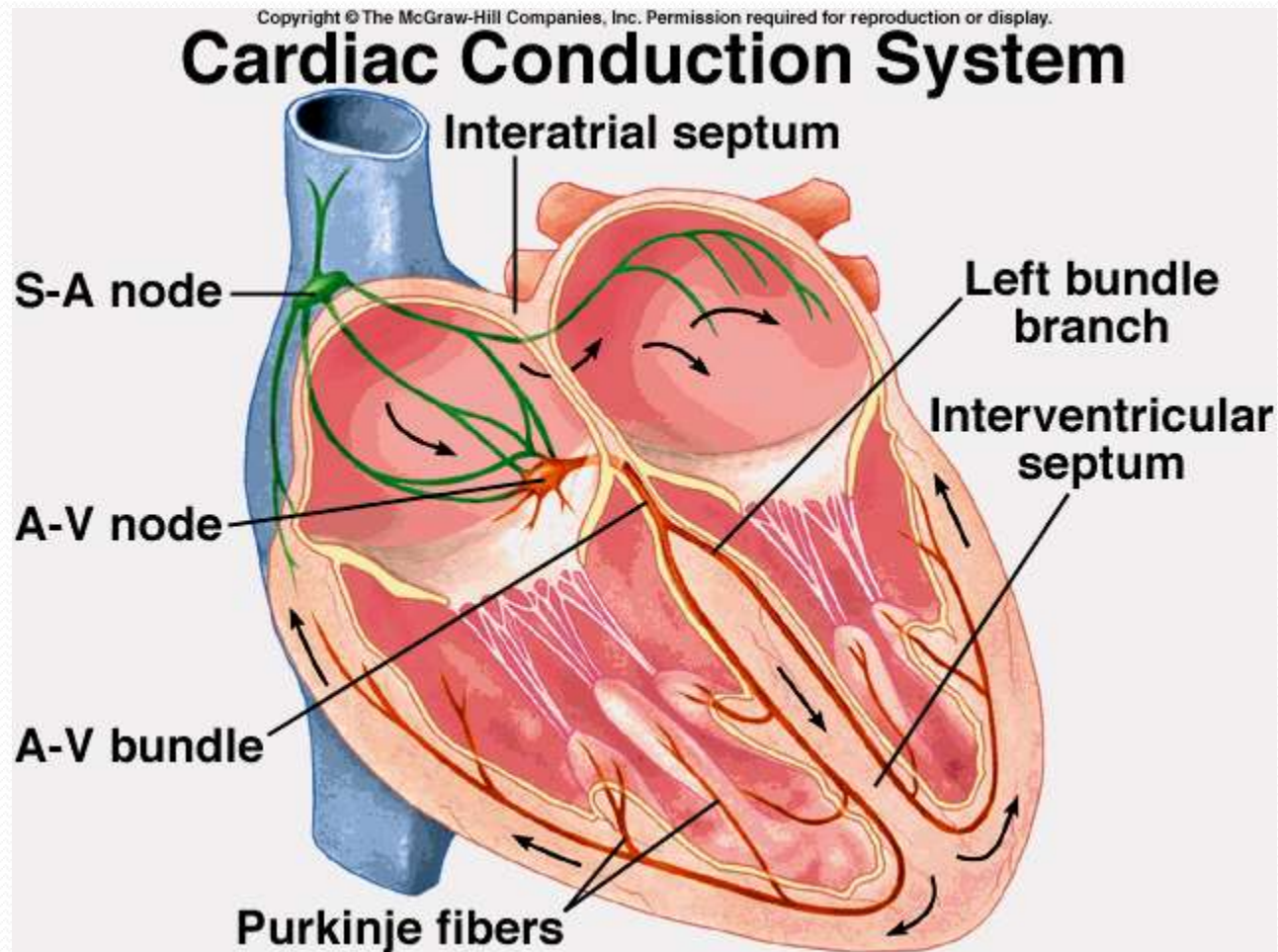
Heart Physiology



Heart Physiology

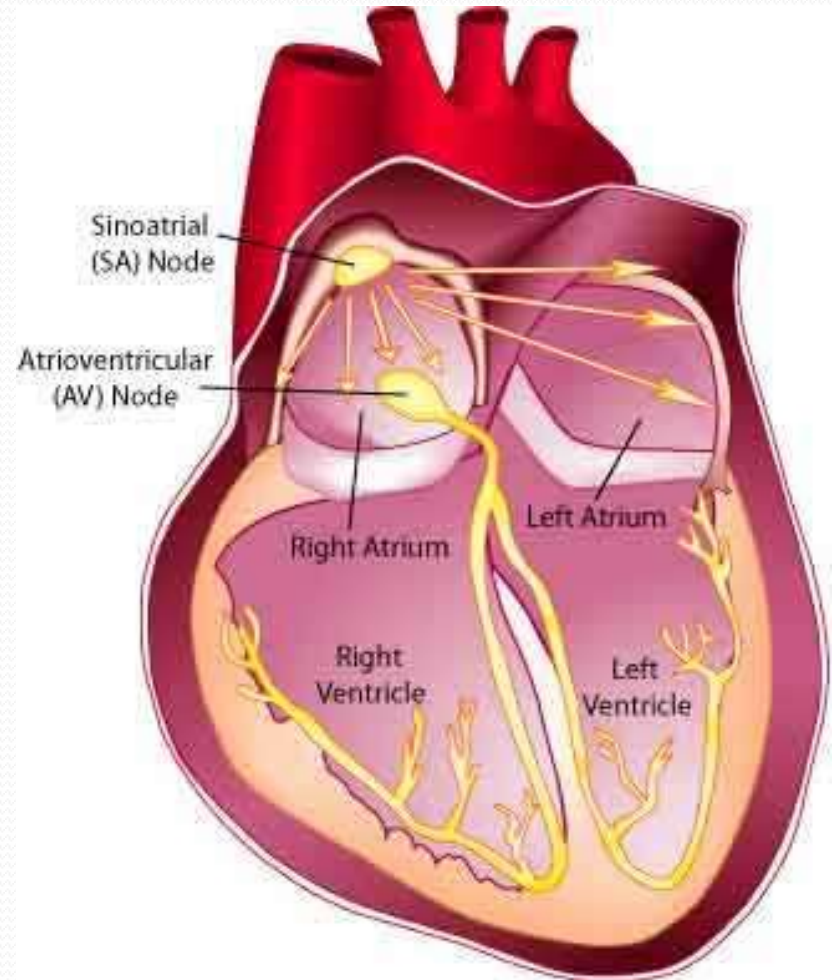
- Components of the Intrinsic Conduction System include:
- The sinoatrial (SA) node is a crescent shaped node in the right atrium
- The atrioventricular (AV) node is at the junction of the atria and ventricles
- The atrioventricular (AV) bundle (bundle of His)
- Branch bundles in the interventricular septum
- Purkinje fibers which spread with the muscle of the ventricle walls

Heart Physiology

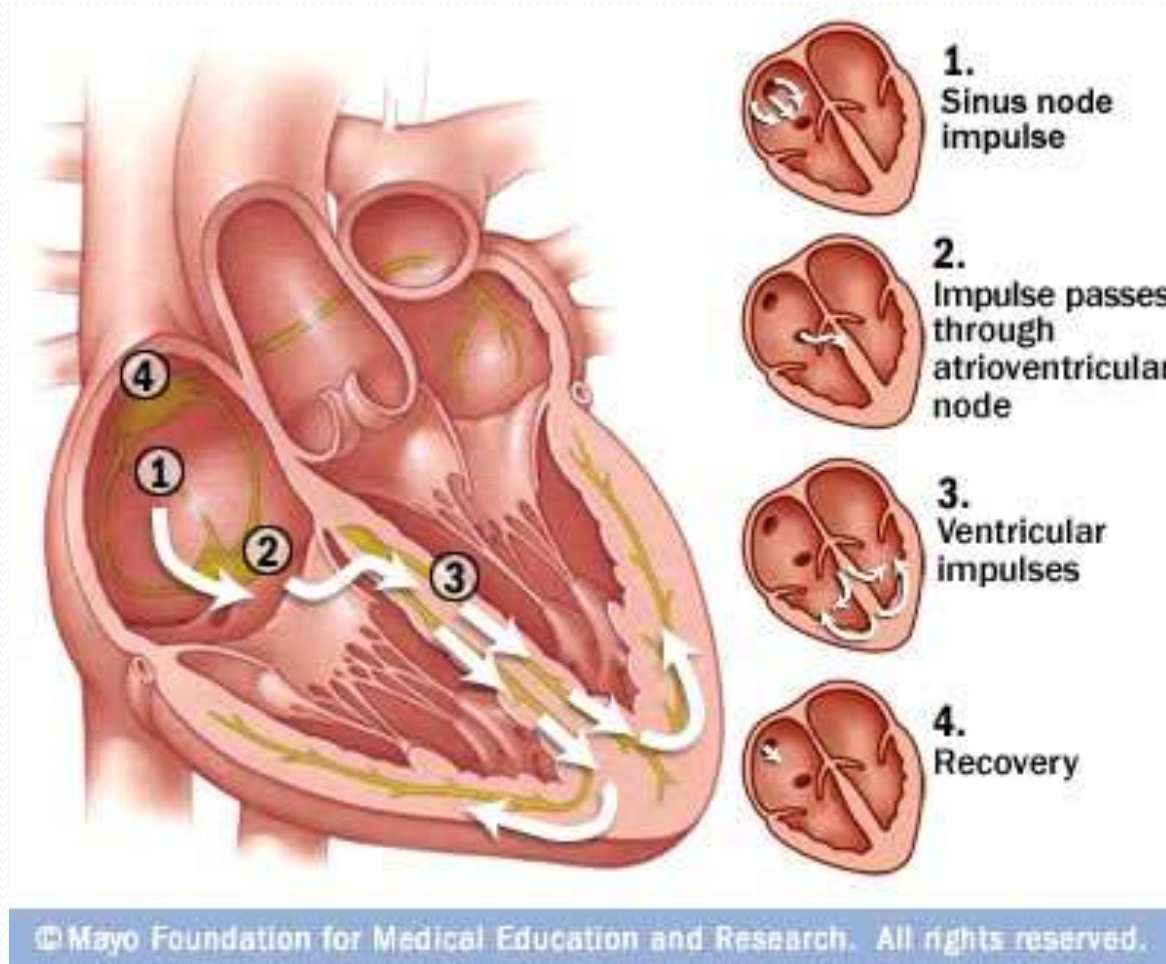


Heart Physiology

- The SA node has the highest rate of depolarization in the whole system
- It starts each heartbeat and sets the pace for the whole heart and is therefore called the pacemaker

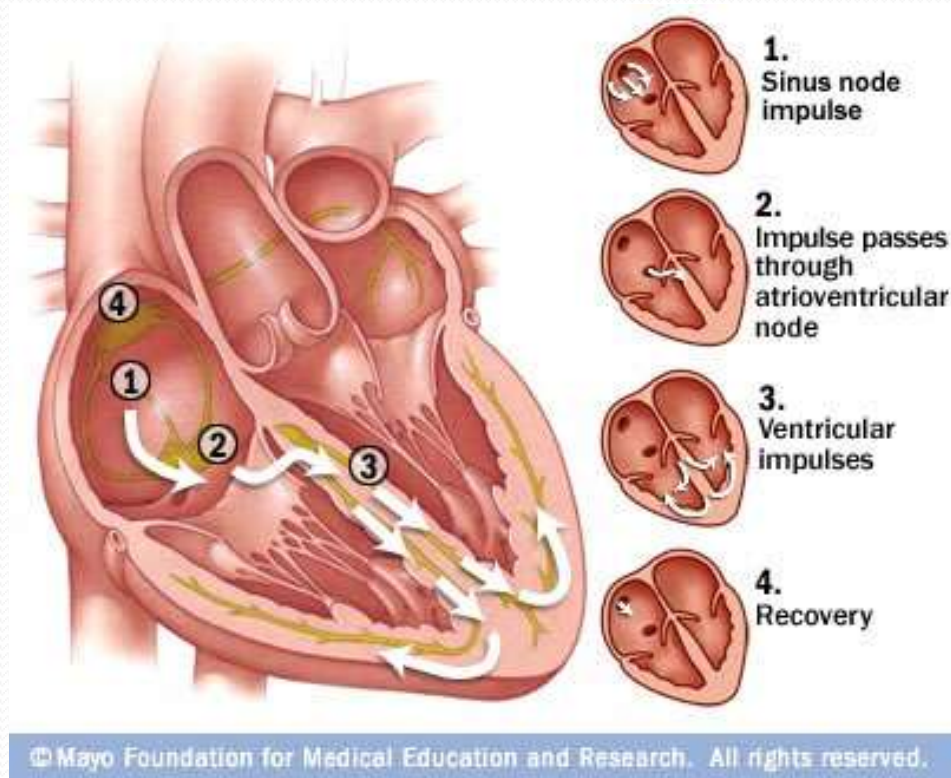


Heart Physiology



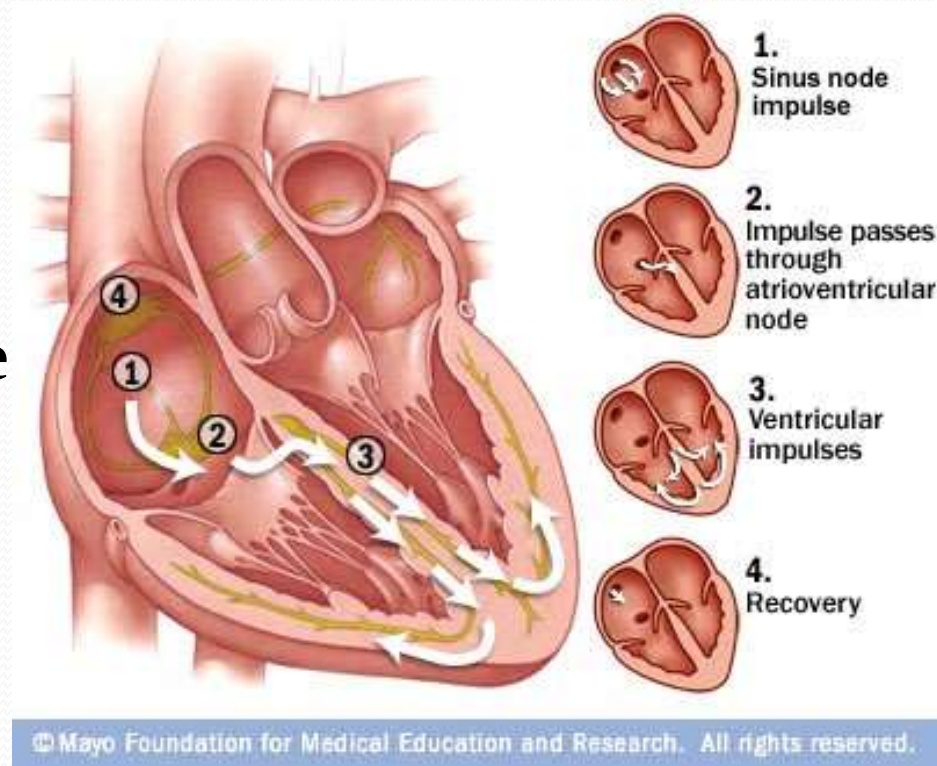
Heart Physiology

- The impulse travels from the SA node through the atria to the AV node, causing the atria to contract



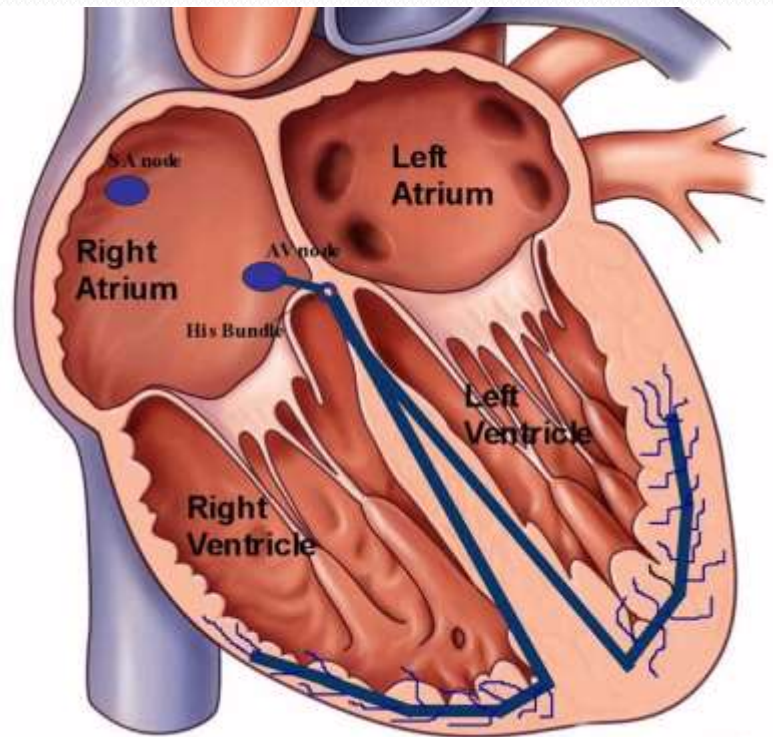
Heart Physiology

- At the AV node, the impulse is delayed to give the atria time to finish contracting
- It then passes rapidly through the AV bundle, the bundle branches, and the Purkinje fibers, causing a “wringing” contraction of the ventricles that begins at the apex and moves toward the atria



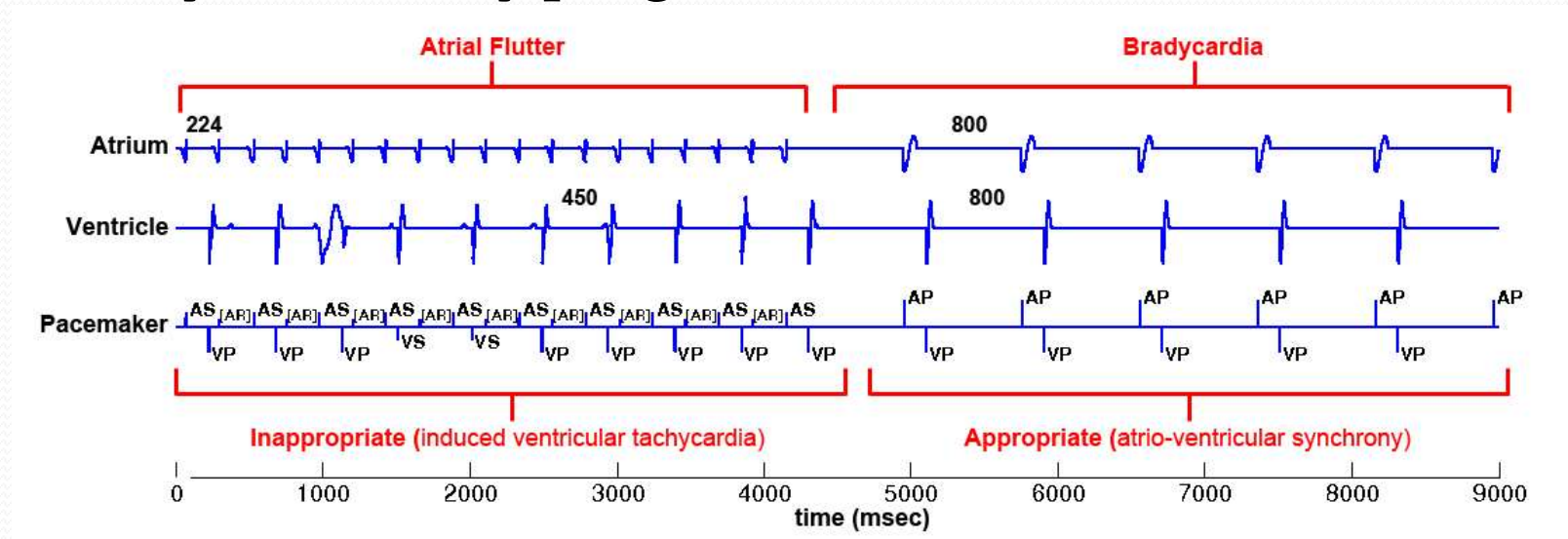
Heart Physiology

- This contraction effectively ejects blood superiorly into the large arteries leaving the heart



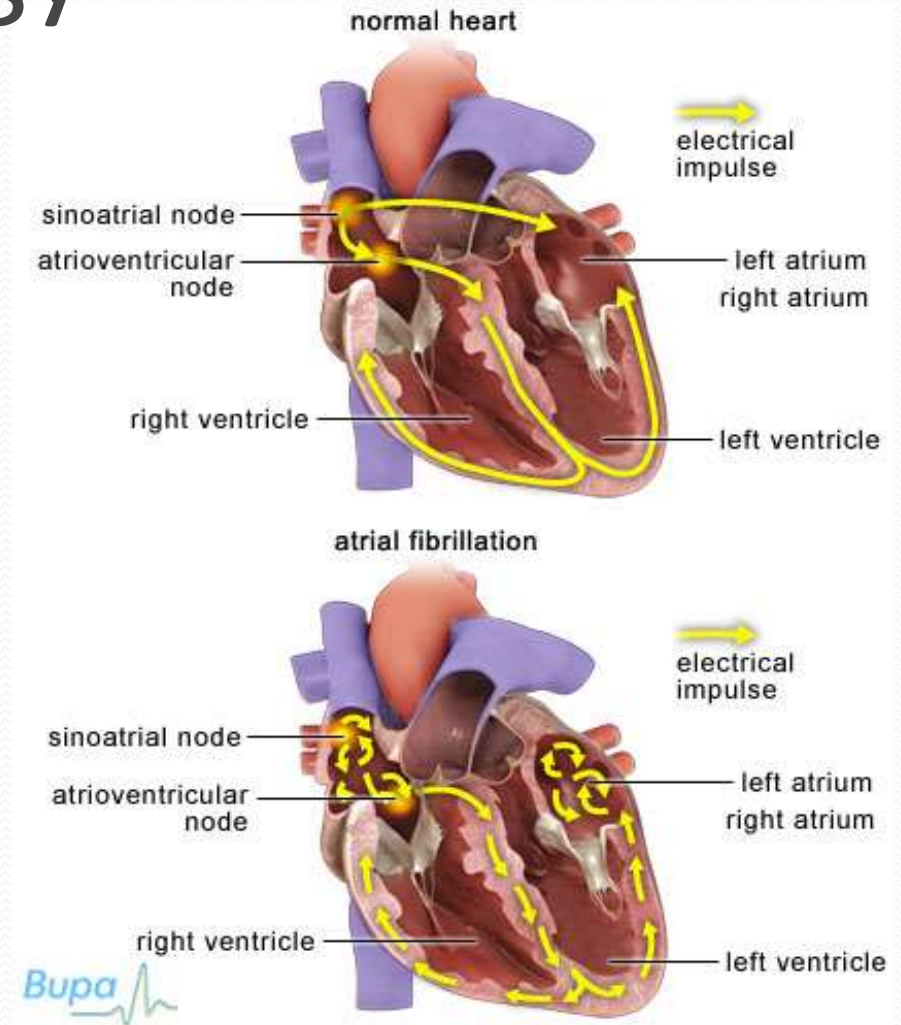
Heart Physiology

- Tachycardia is a rapid heart rate (> 100 bpm)
- Bradycardia is a slow heart rate (< 60 bpm)
- Neither condition is pathological, but prolonged tachycardia may progress to fibrillation



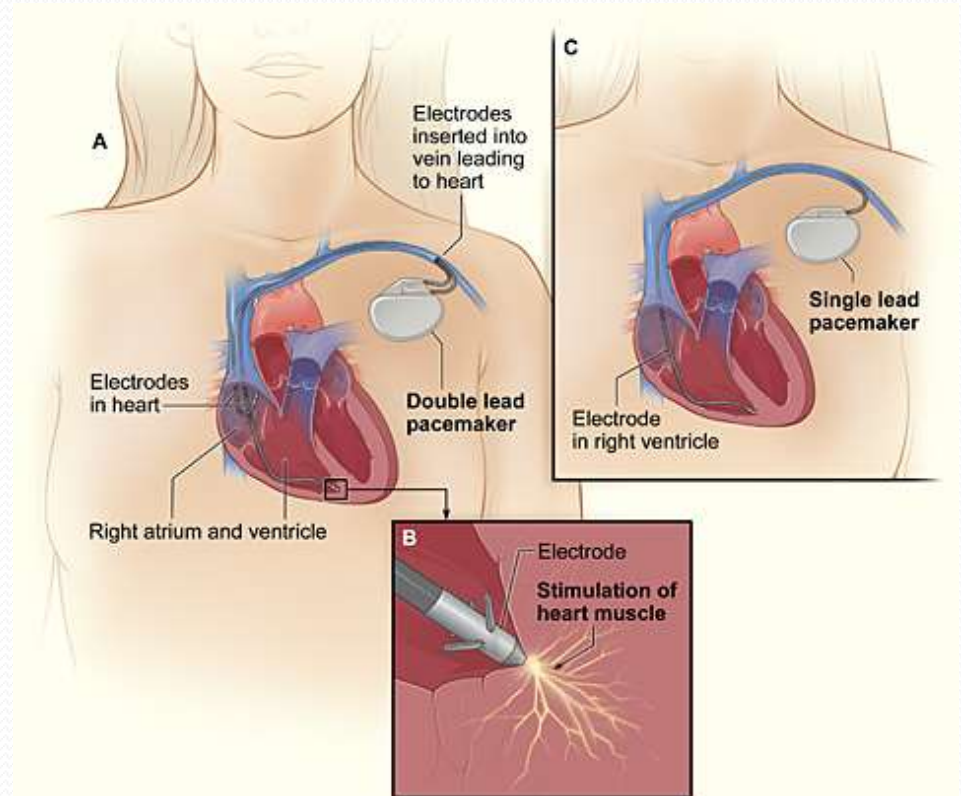
Heart Physiology

- Fibrillation is a rapid, uncoordinated shuddering of the heart muscle
- Fibrillation makes the heart totally useless as a pump and is a major cause of death from heart attacks in adults



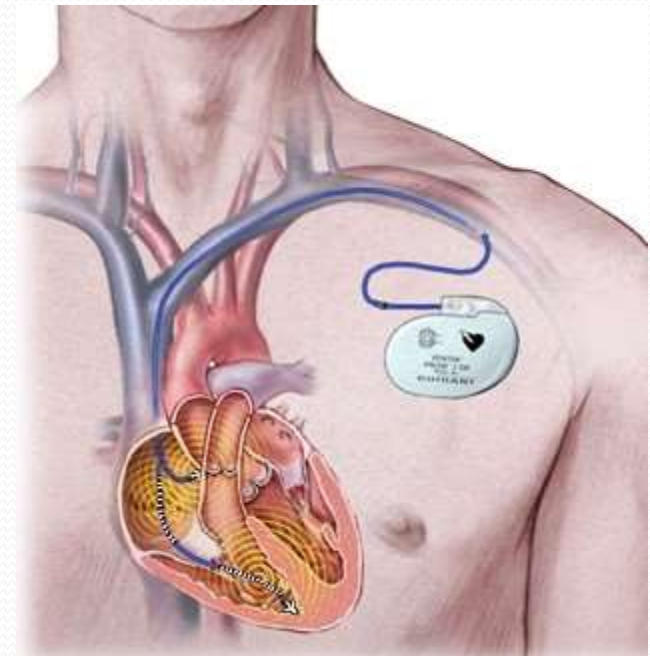
Heart Physiology

- A pacemaker is a small device, about the size of a half dollar piece, placed under the skin near the heart to help control the heartbeat.
- A pacemaker is implanted as part of what's often referred to as "cardiac resynchronization therapy."

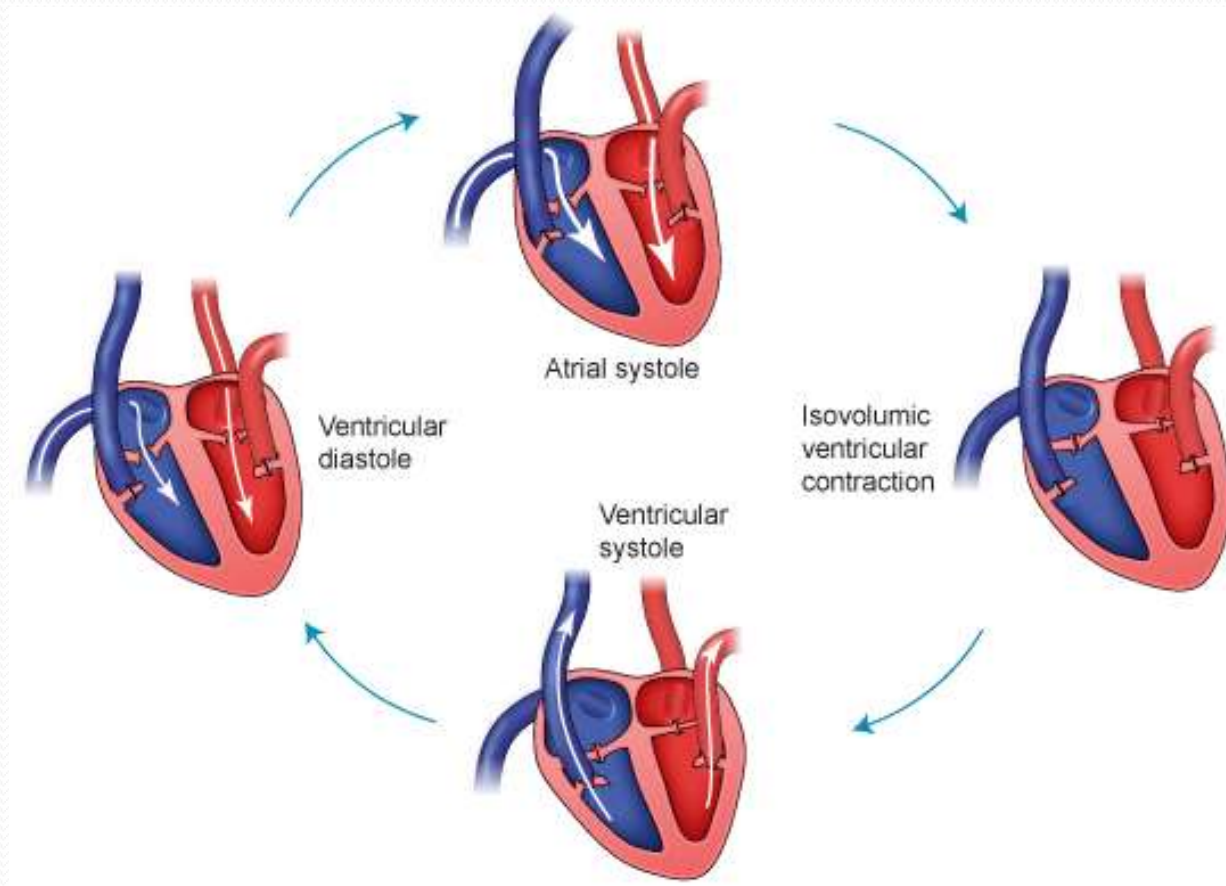


Heart Physiology

- People may need a pacemaker for a variety of reasons — mostly due to one of a group of conditions called arrhythmias, in which the heart's rhythm is abnormal
- They can be implanted temporarily to treat a slow heartbeat after a heart attack, surgery or overdose of medication
- Pacemakers can also be implanted permanently to correct bradycardia or to help treat heart failure

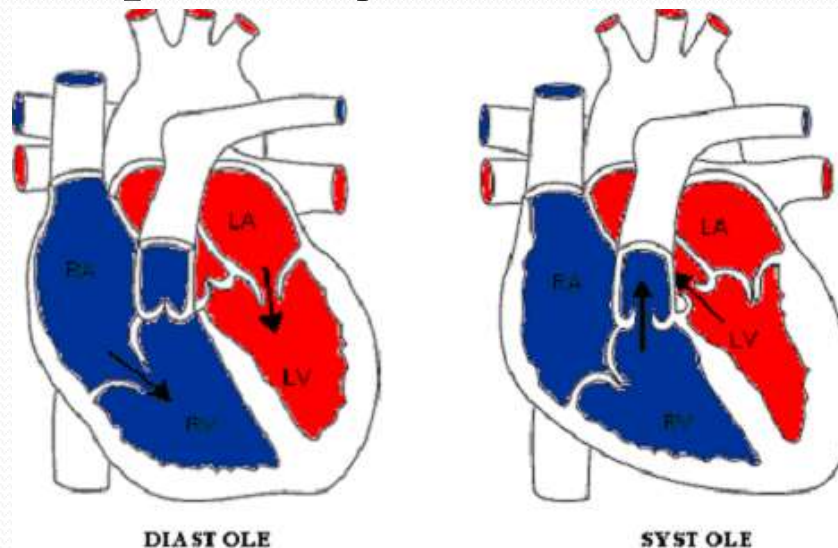


Cardiac Cycle and Heart Sounds



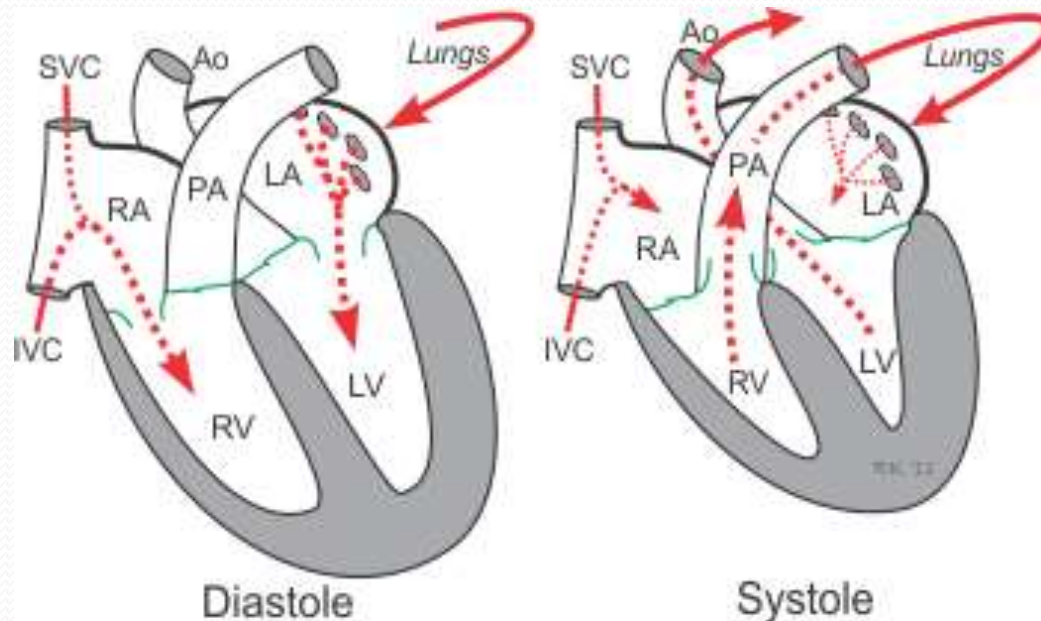
Cardiac Cycle and Heart Sounds

- In a healthy heart, the atria contract simultaneously
- When they start to relax, contraction of the ventricles begins
- Systole and diastole mean heart contraction and relaxation respectively



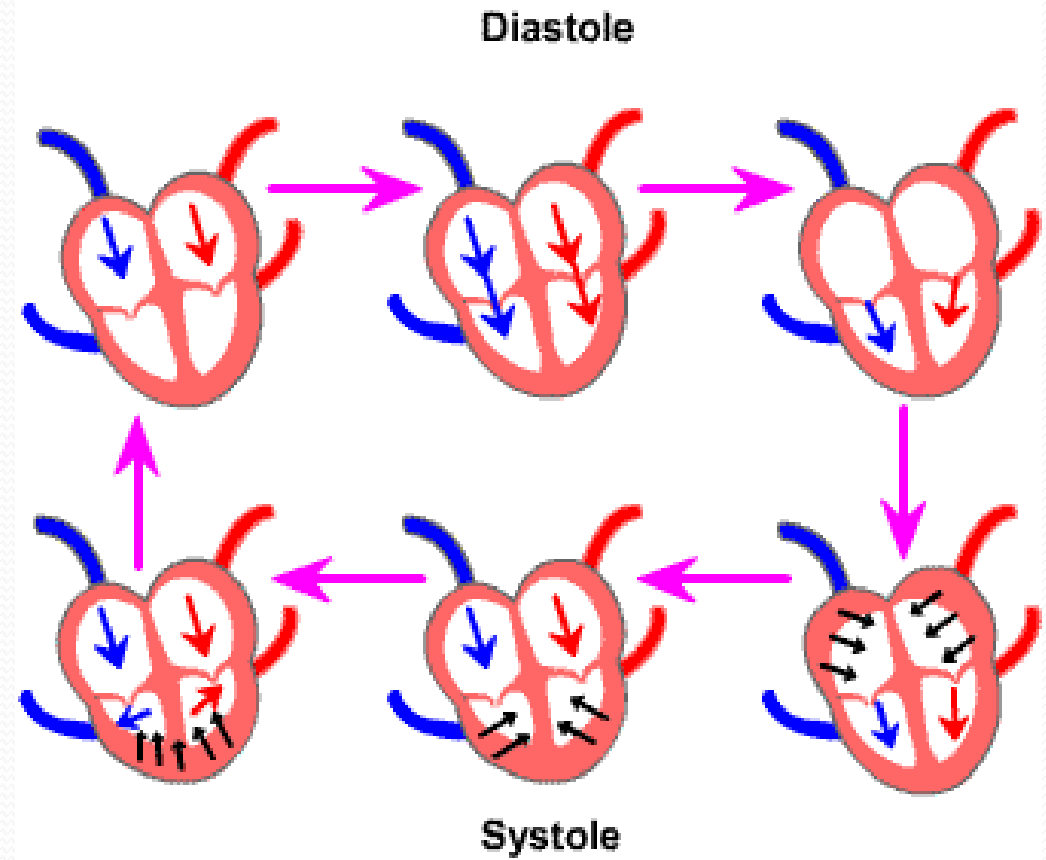
Cardiac Cycle and Heart Sounds

- Because most of the pumping work is done by the ventricles, these terms always refer to the contraction and relaxation of the ventricles unless otherwise stated



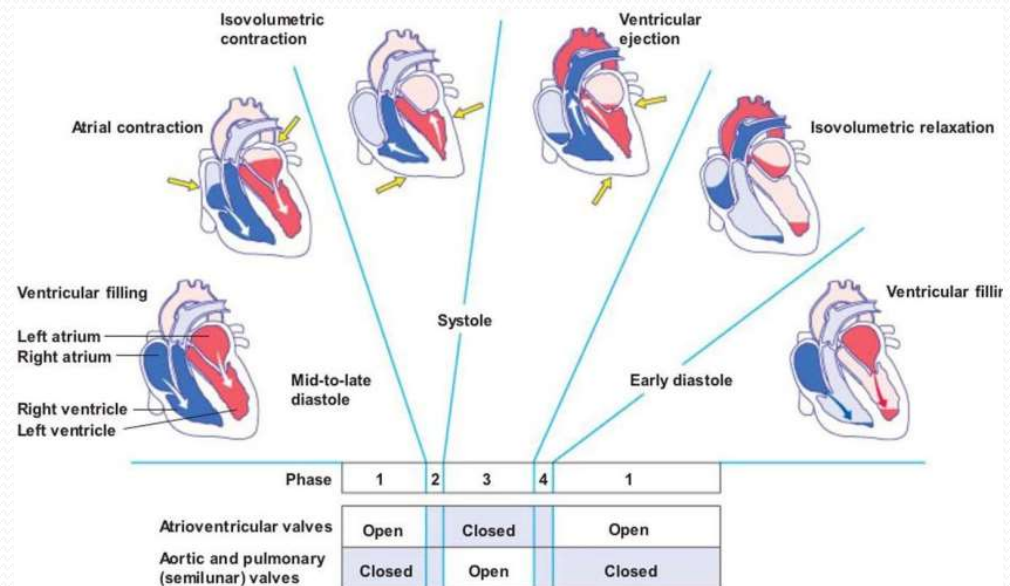
Cardiac Cycle and Heart Sounds

- The term cardiac cycle refers to the events of one complete heartbeat, during which both atria and ventricles contract and then relax



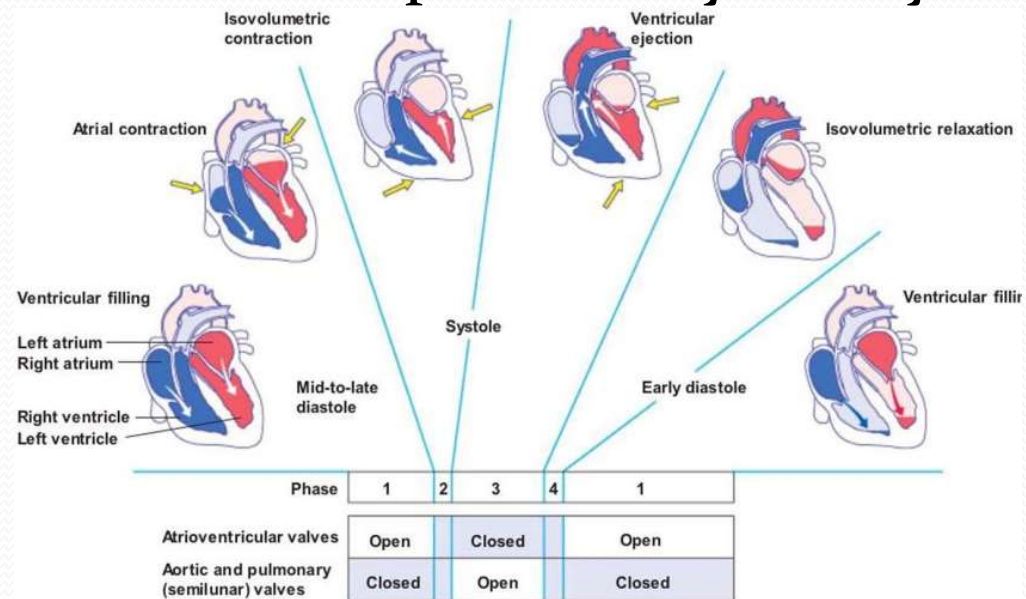
Cardiac Cycle and Heart Sounds

- The average heart beats 75 times per minute
- The average length of a cardiac cycle is 0.8 seconds
- The cardiac cycle occurs in three major steps:
 1. mid-to-late diastole
 2. ventricular systole
 3. early diastole



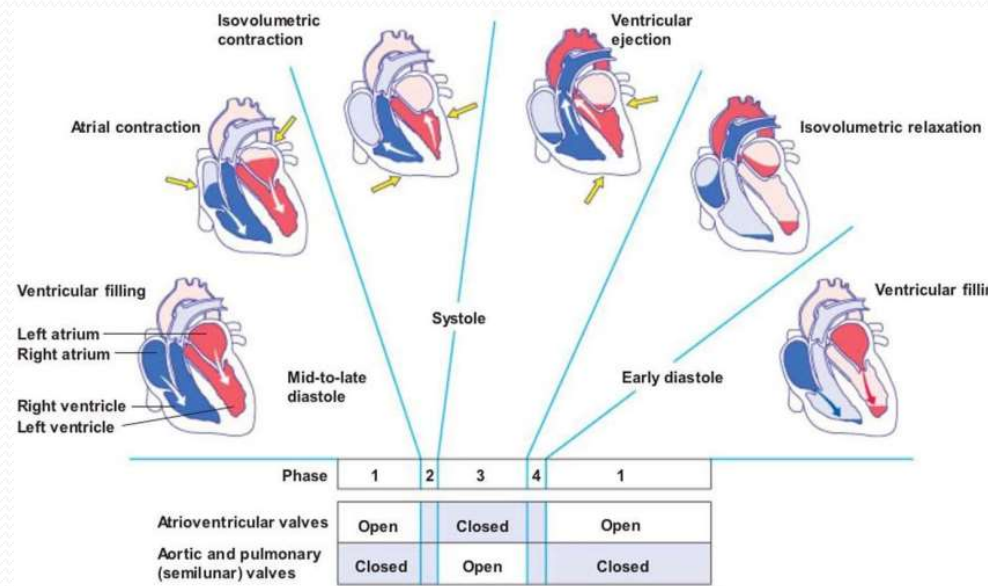
1. Mid-to-late diastole

- The heart is in complete relaxation
- Pressure in the heart is low
- Blood is flowing passively into and through the atria and into the ventricles from pulmonary and systemic circulations

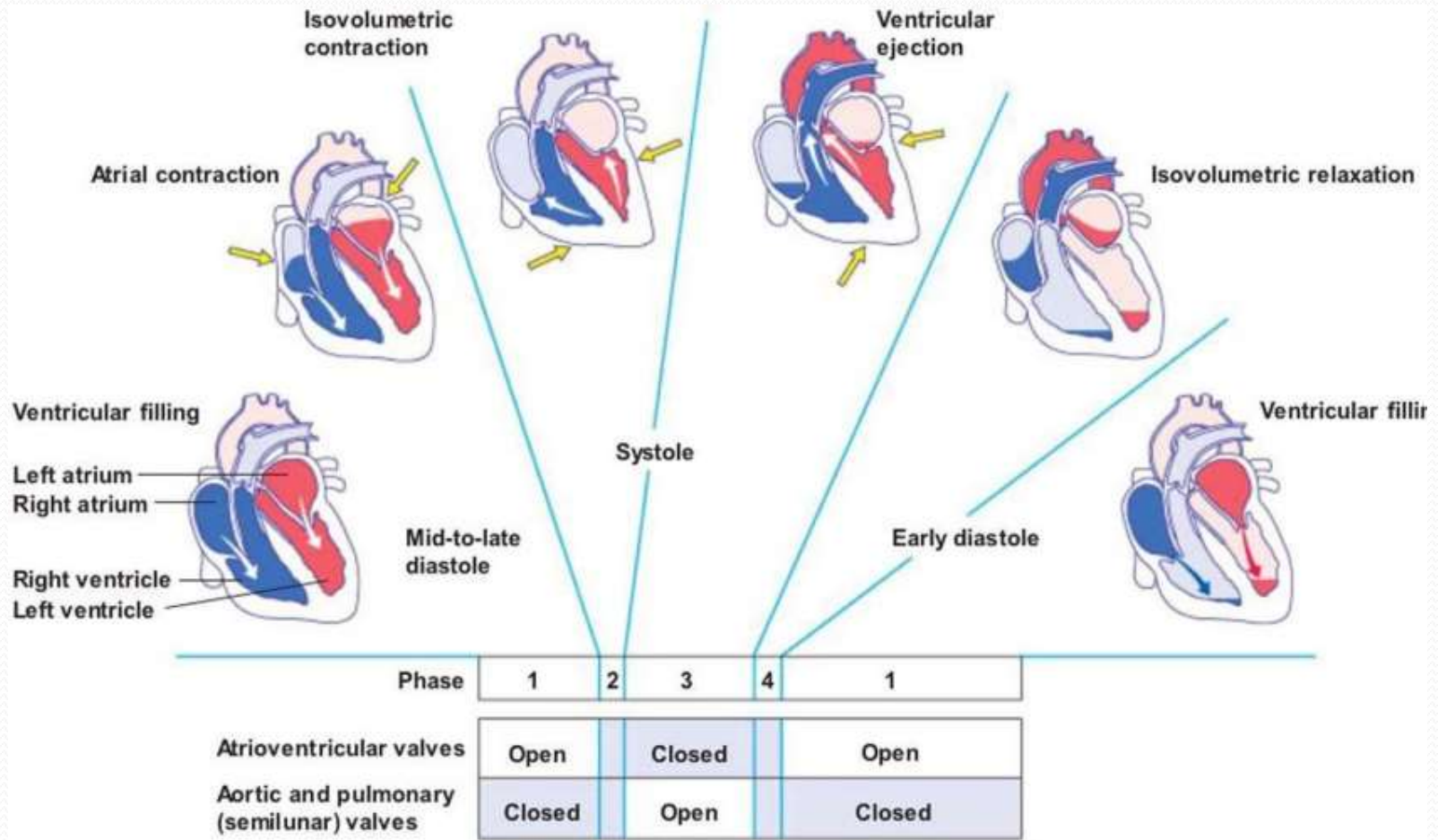


1. Mid-to-late diastole

- The semilunar valves are closed
- The AV valves are open
- Then the atria contract and force the blood into the ventricles

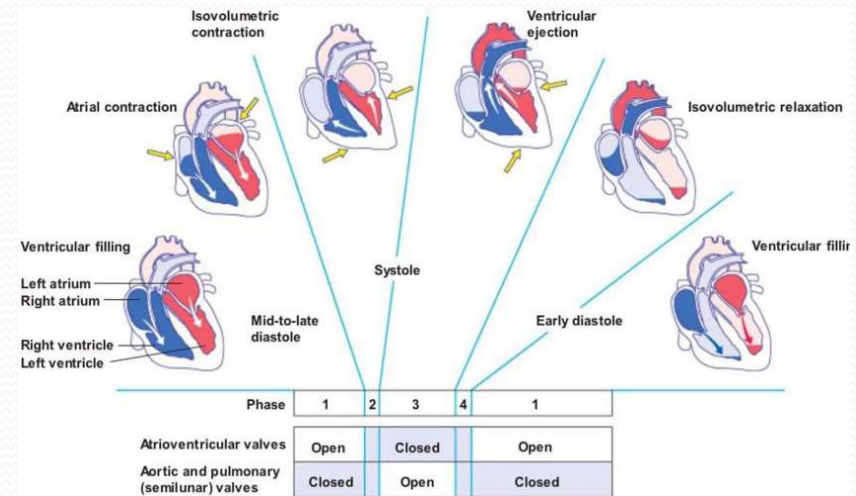


Cardiac Cycle

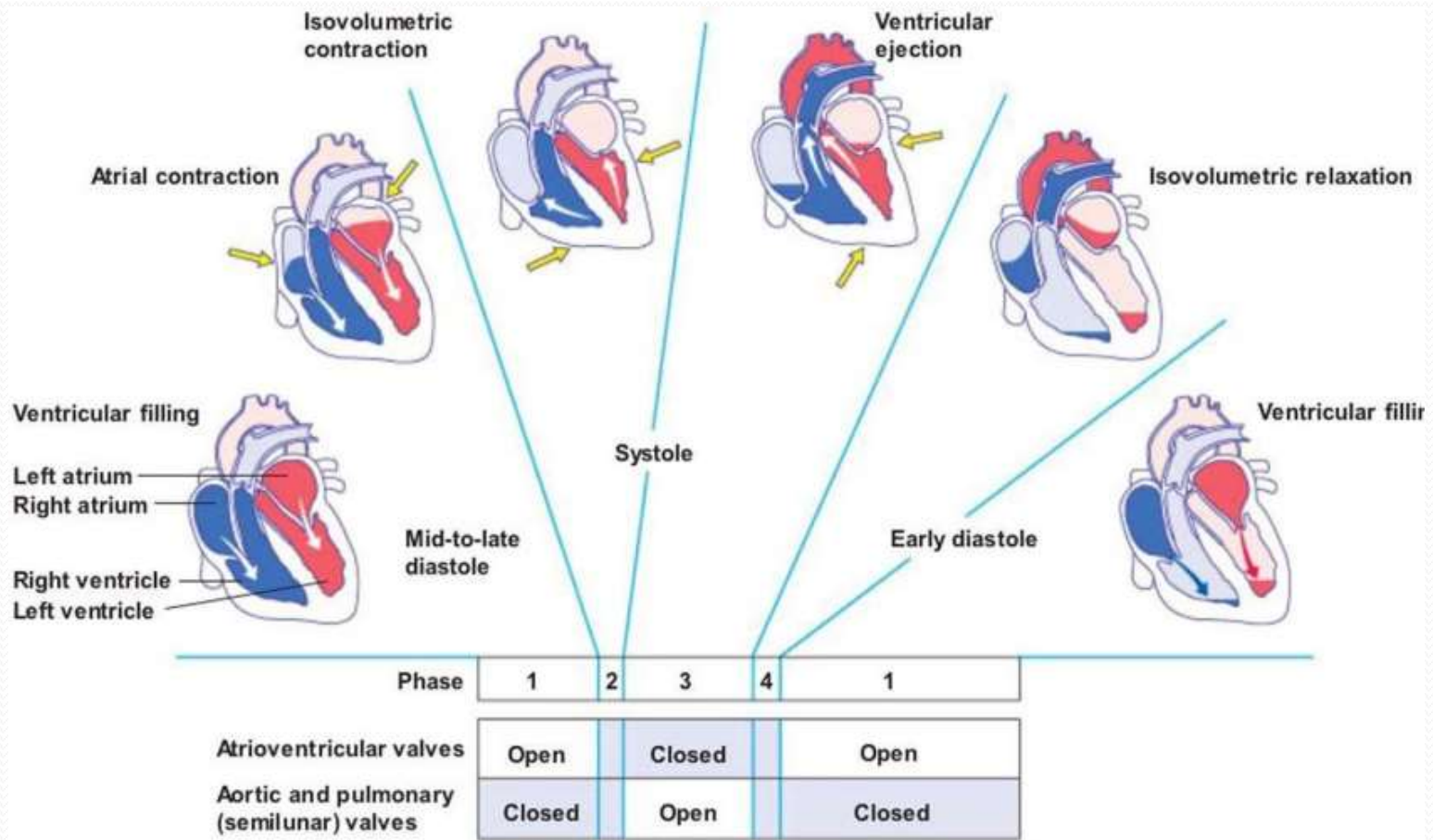


2. Ventricular systole

- The pressure within the ventricles increases rapidly, closing the AV valves
- When the intraventricular pressure is higher than the pressure in the large arteries leaving the heart, the semilunar valves are forced open, and blood rushes out of the ventricles
- The atria are relaxed, and again are filling with blood

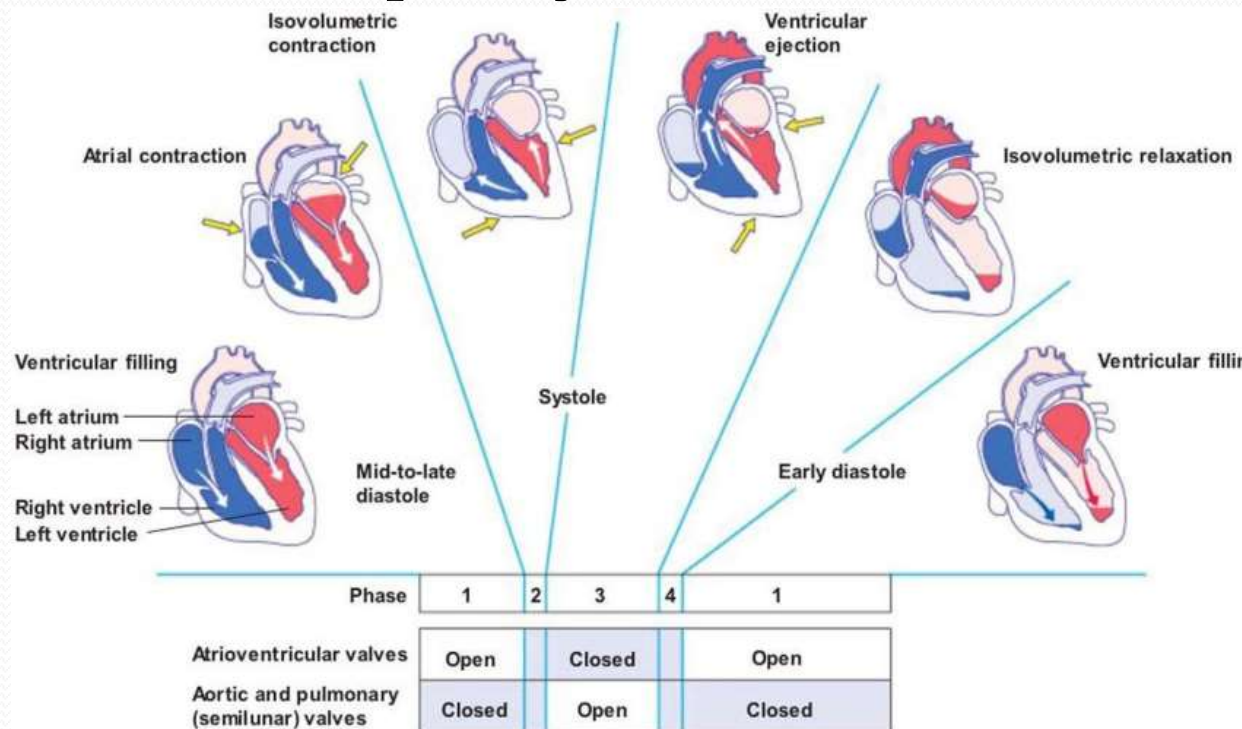


Cardiac Cycle



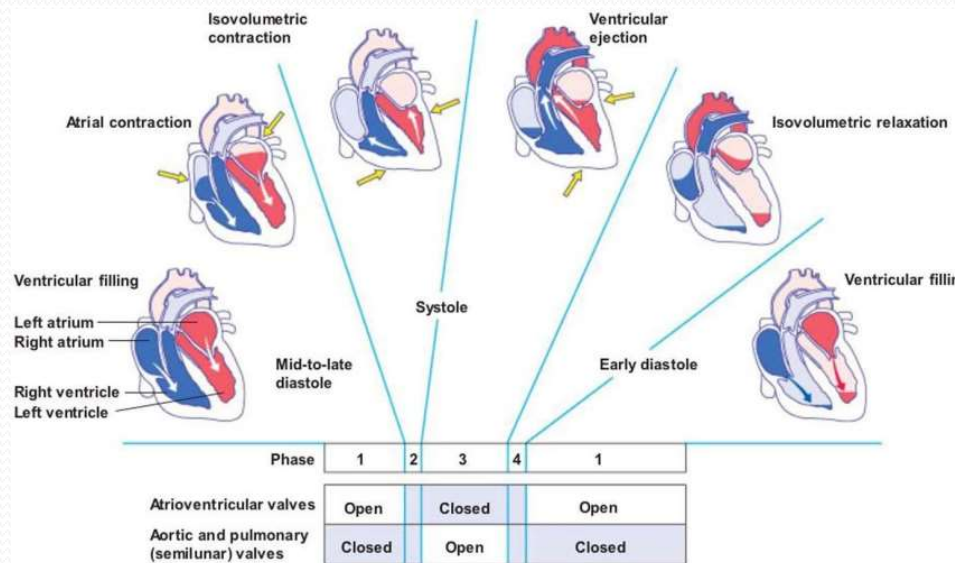
3. Early diastole

- At the end of systole, the ventricles relax, the semilunar valves snap shut, and for a moment the ventricles are completely closed chambers

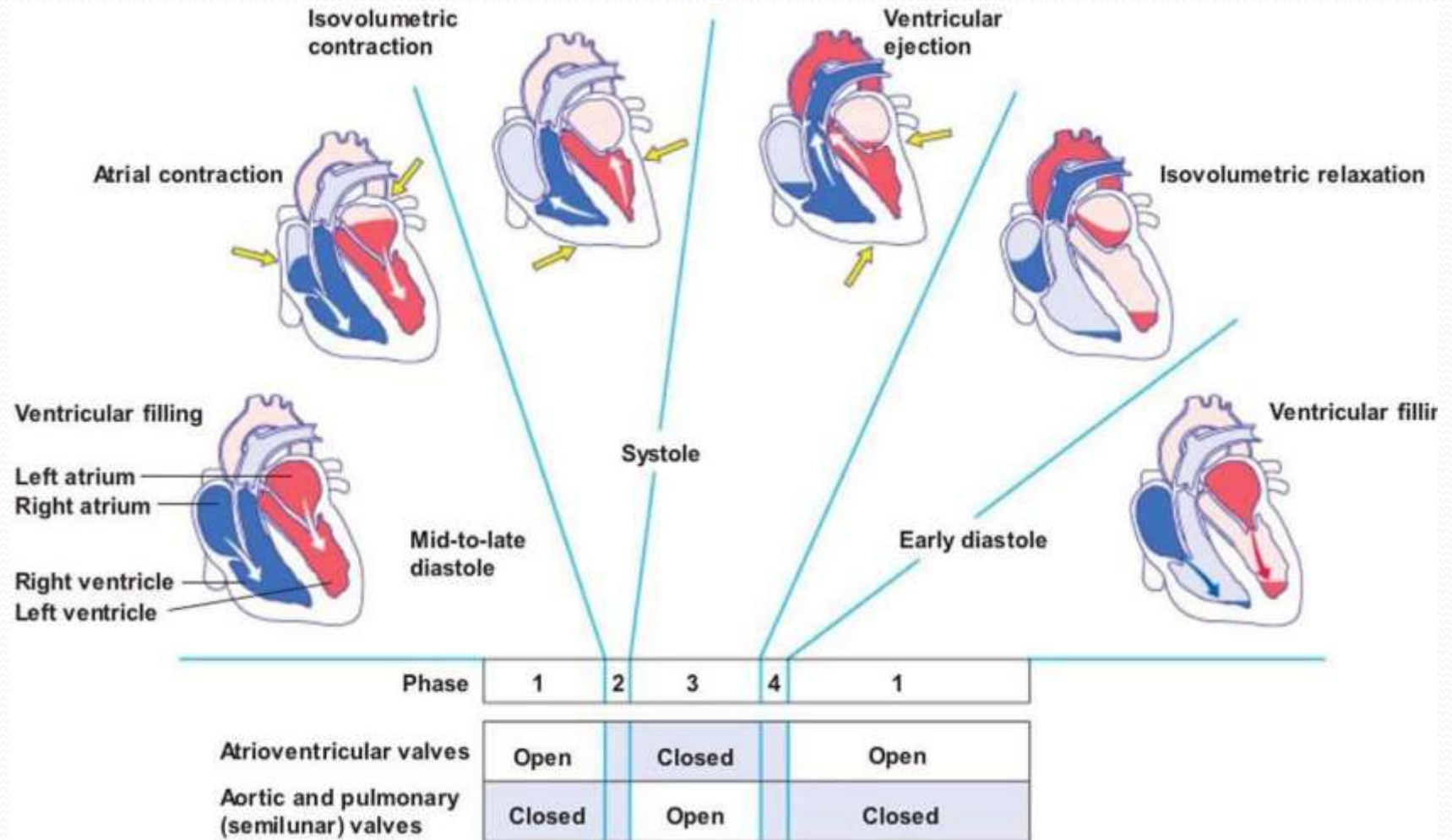


3. Early diastole

- During early diastole, the intraventricular pressure drops
- When it drops below the pressure in the atria, the AV valves are forced open. And the ventricles again begin to refill rapidly with blood



Cardiac Cycle



Heart Sounds

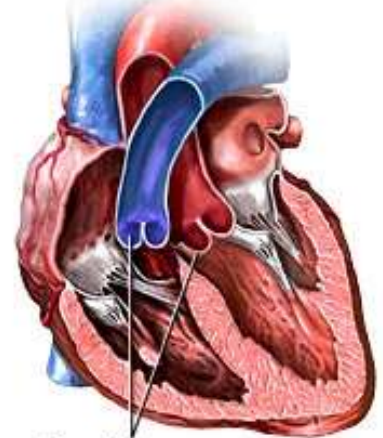
- When using a stethoscope, the heart beat usually has two distinct sounds – “lub” and “dup”
- These are caused by the closing of the two sets of valves
- “lub” – AV valves
- “dup” – semilunar valves

First heart sound,
“lub”, occurs when
atrioventricular valves
close



Atrioventricular
valves

Second heart sound,
“dup”, occurs when
semilunar valves close



Semilunar
valves

Cardiac Output



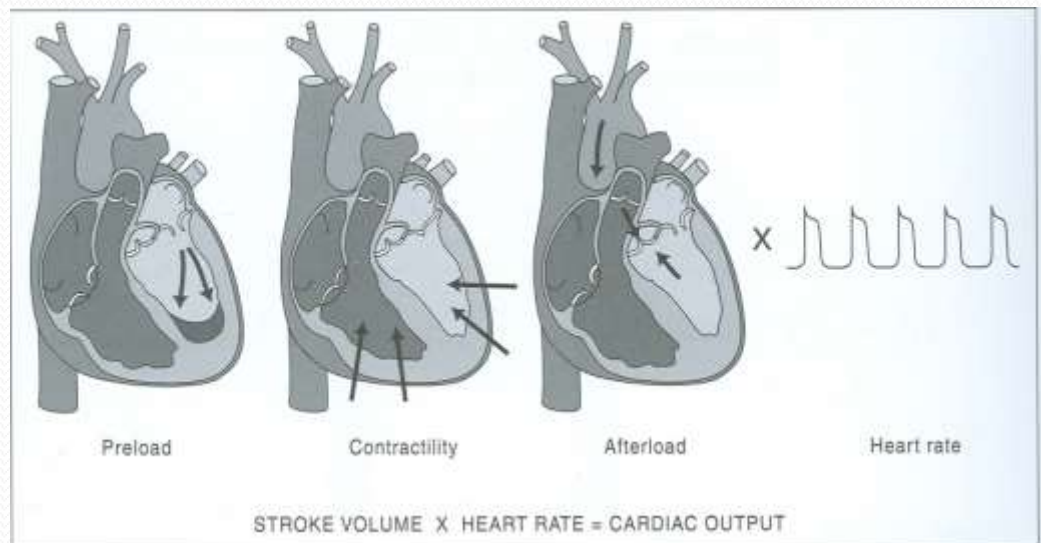
Cardiac Output

- Cardiac Output (CO) is the amount of blood pumped out by each side of the heart in 1 minute
- It is the product of heart rate (HR) and stroke volume (SV)



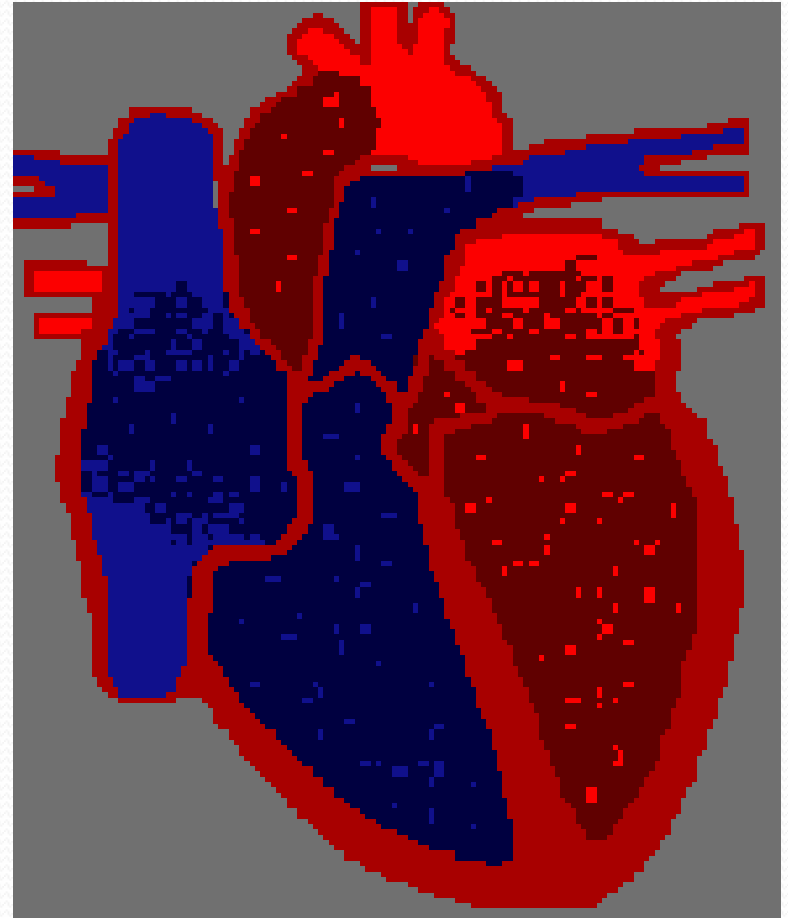
Cardiac Output

- In general, stroke volume increases as the force of ventricular contraction increases
- Let's look at normal resting heart rate and volume:
- $CO = HR \times SV$
- $CO = (75 \text{ bpm}) \times (70 \text{ ml per beat})$
- $CO = 5250 \text{ ml/min}$



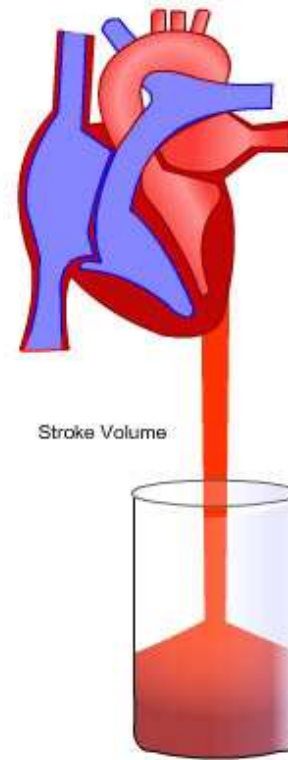
Cardiac Output

- A healthy heart pumps out about 60% of blood in the ventricles (~70 ml) per heart beat
- The critical factor is how much the cardiac muscle cells stretch just before contracting



Cardiac Output

- The important factor stretching the heart muscle is venous return, the amount of blood entering the heart and distending the ventricles
- The more the heart muscles stretch, the stronger the contraction



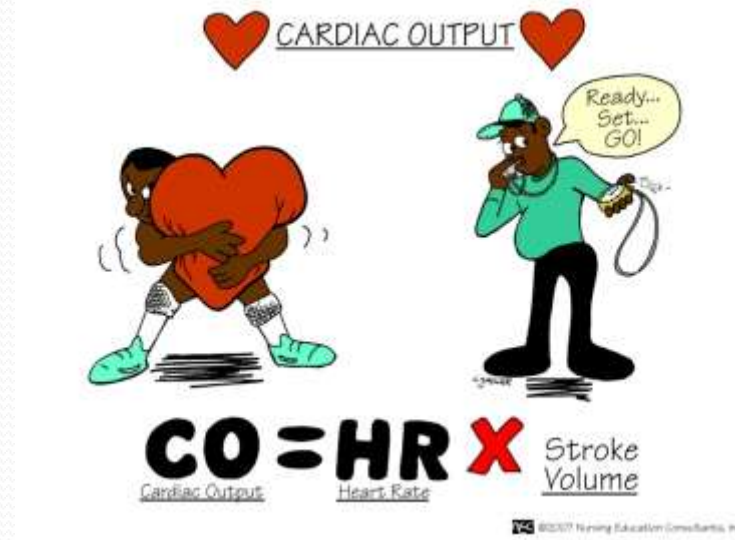
To increase cardiac output

Increase stroke volume
or

Increase heart rate
or
increase both

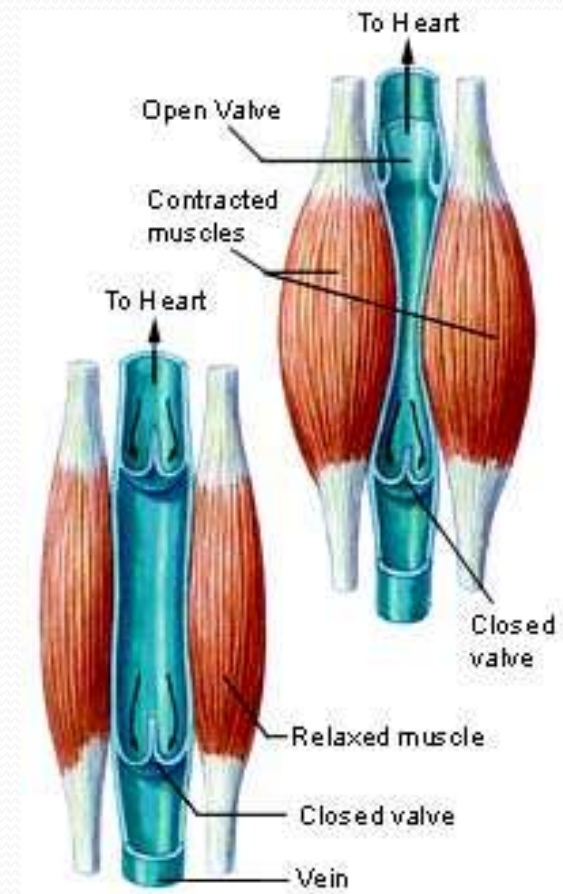
Cardiac Output

- If one side of the heart suddenly begins to pump more blood than the other, the increased venous return to the opposite ventricle will force it to pump out an equal amount, thus preventing backup of blood in the circulation



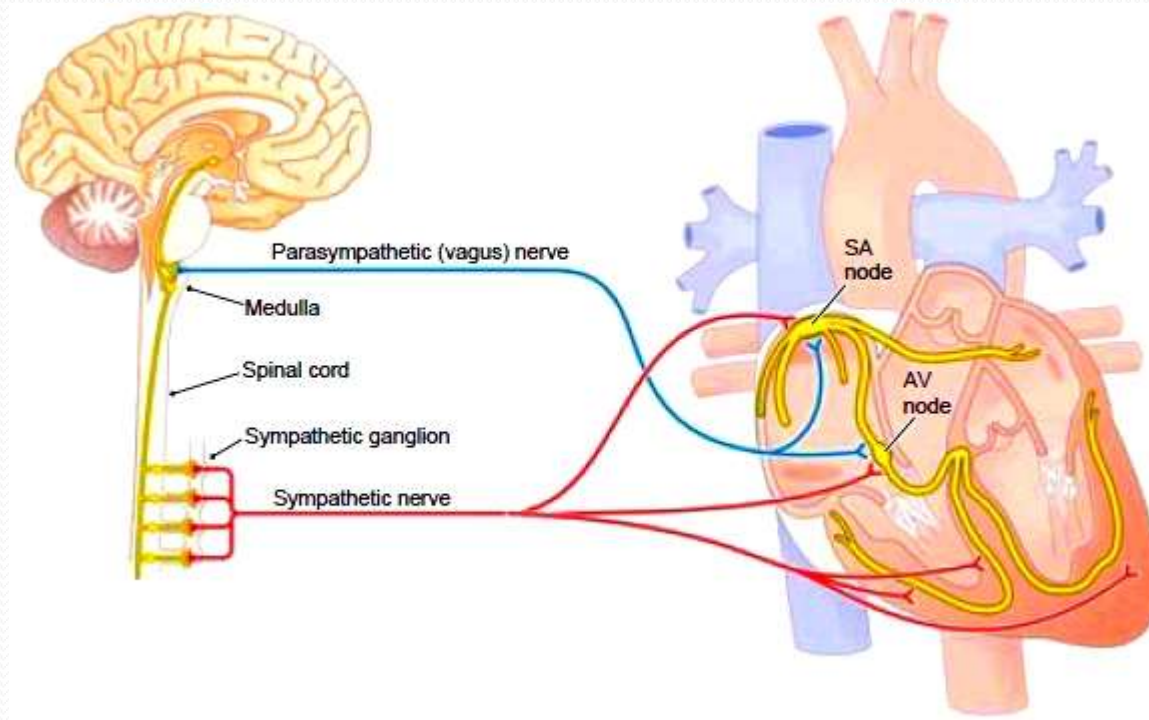
Cardiac Output

- The enhanced squeezing action of active skeletal muscles from exercise speeds up venous return
- Severe blood loss or rapid heart rate, decreases stroke volume, creating less venous return



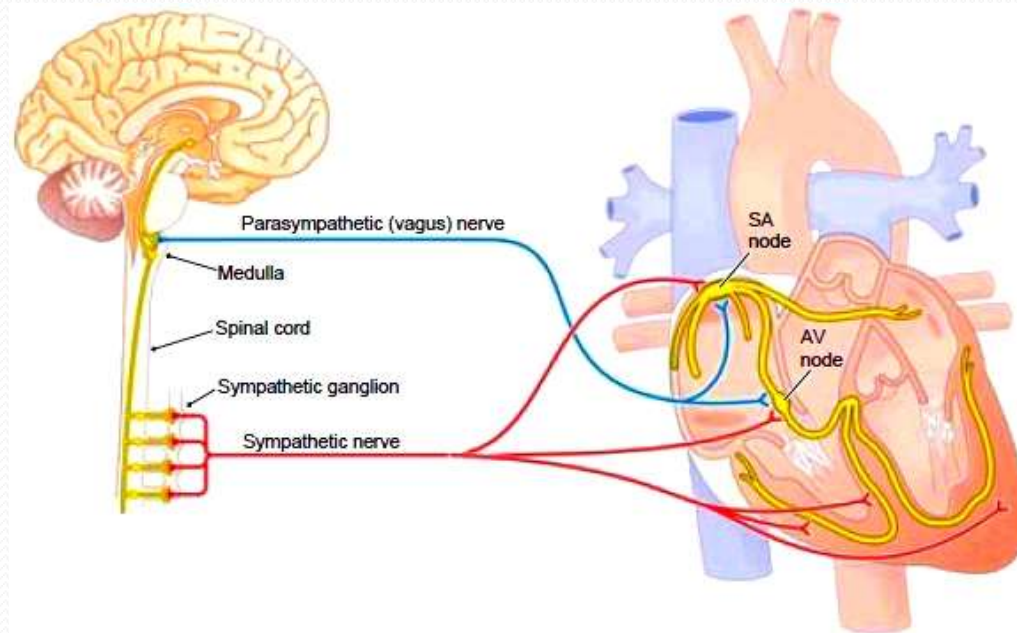
Factors Modifying Basic Heart Rate

- Heart contraction does not depend on the nervous system, but it can be changed temporarily by the ANS
- It is also modified by chemicals, hormones and ions



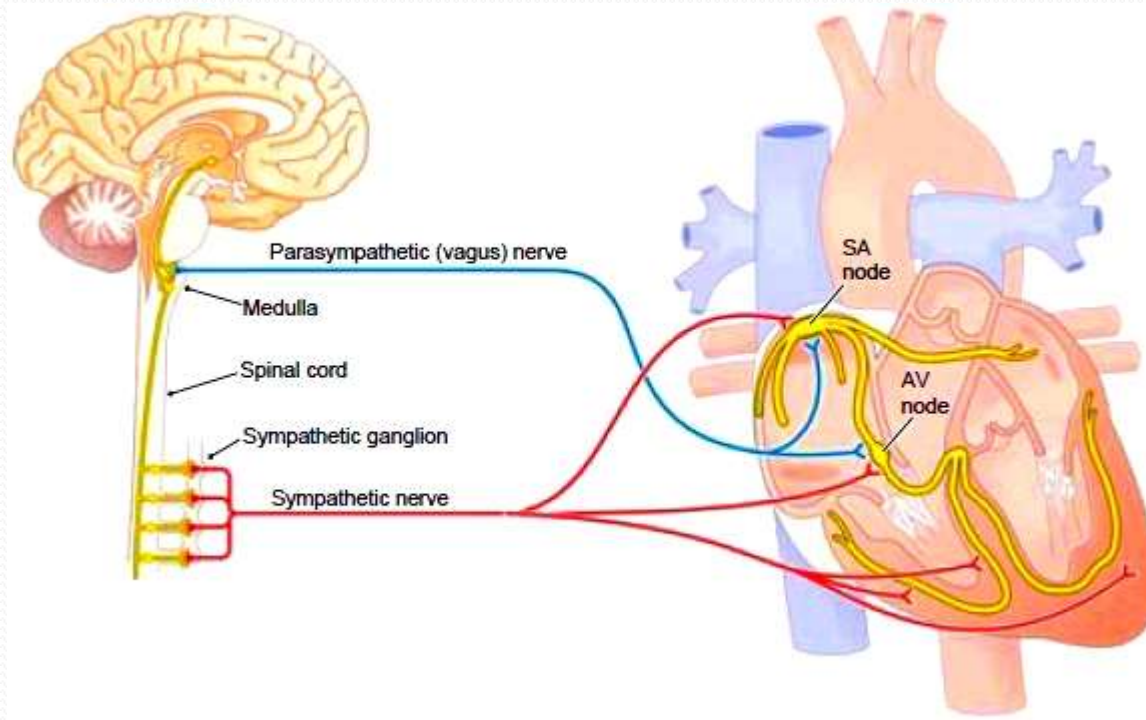
Neural (ANS) Control

- During times of physical or emotional stress, the nerves of sympathetic division stimulate the SA and AV nodes and the cardiac muscles
- The heart beats more rapidly



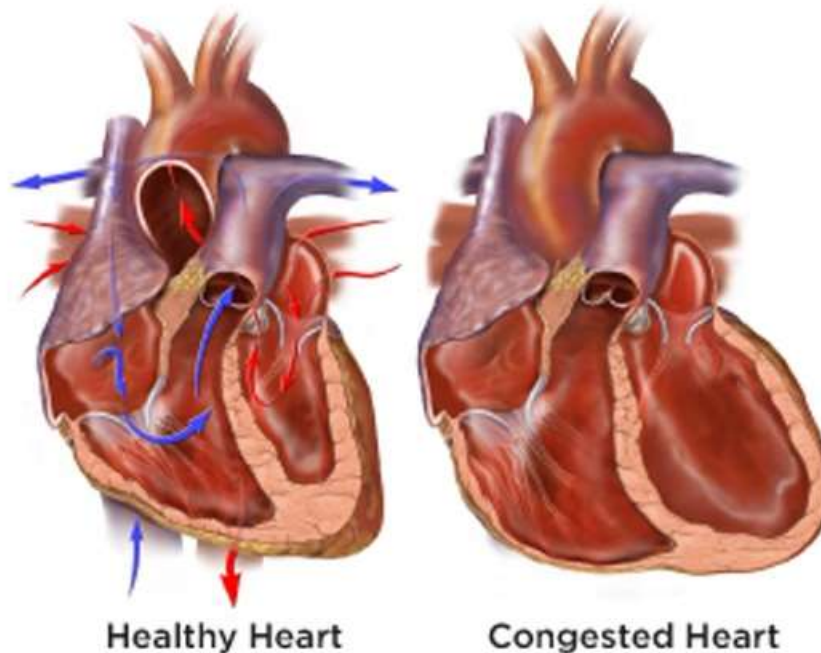
Neural (ANS) Control

- When the demand declines, the heart adjusts, the parasympathetic nerves slow and steady the heart rate
- Gives the heart time to recover and rest

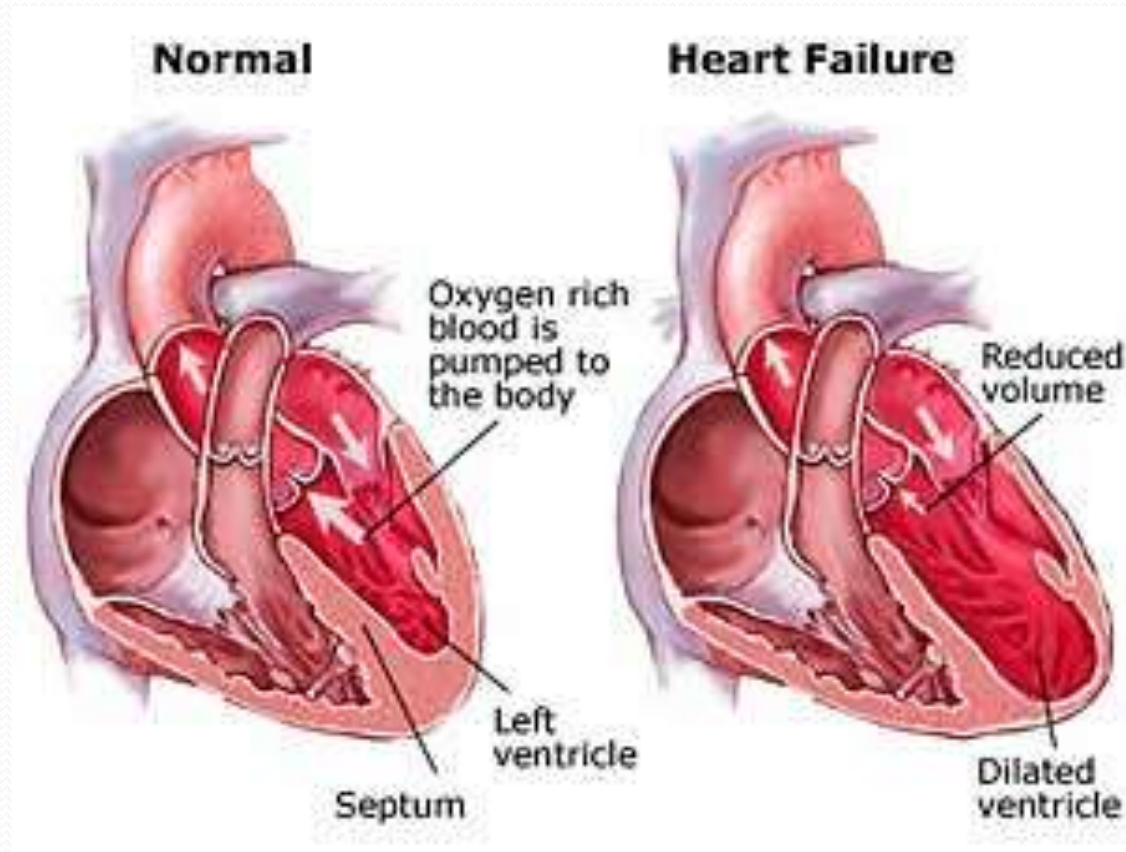


Neural (ANS) Control

- In patients with Congestive Heart Failure (CHF), or other heart disease the heart pumps weakly
- Some medications can be used to enhance contractile force and stroke volume of the heart, improving cardiac output



Congestive Heart Failure

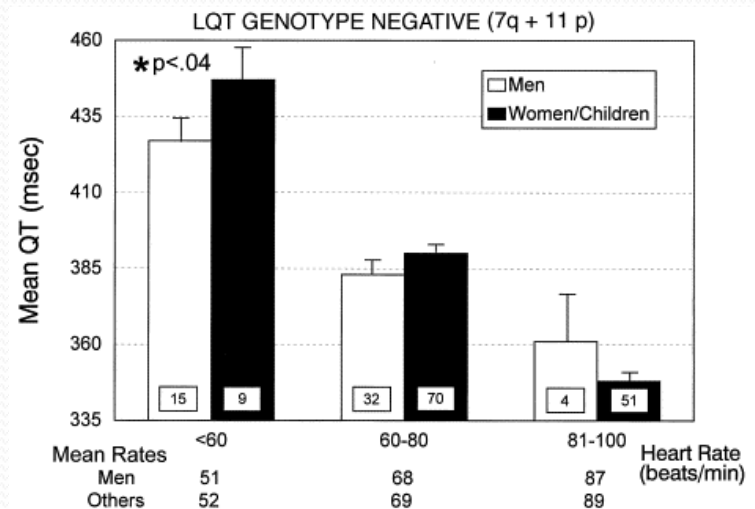


Neural (ANS) Control

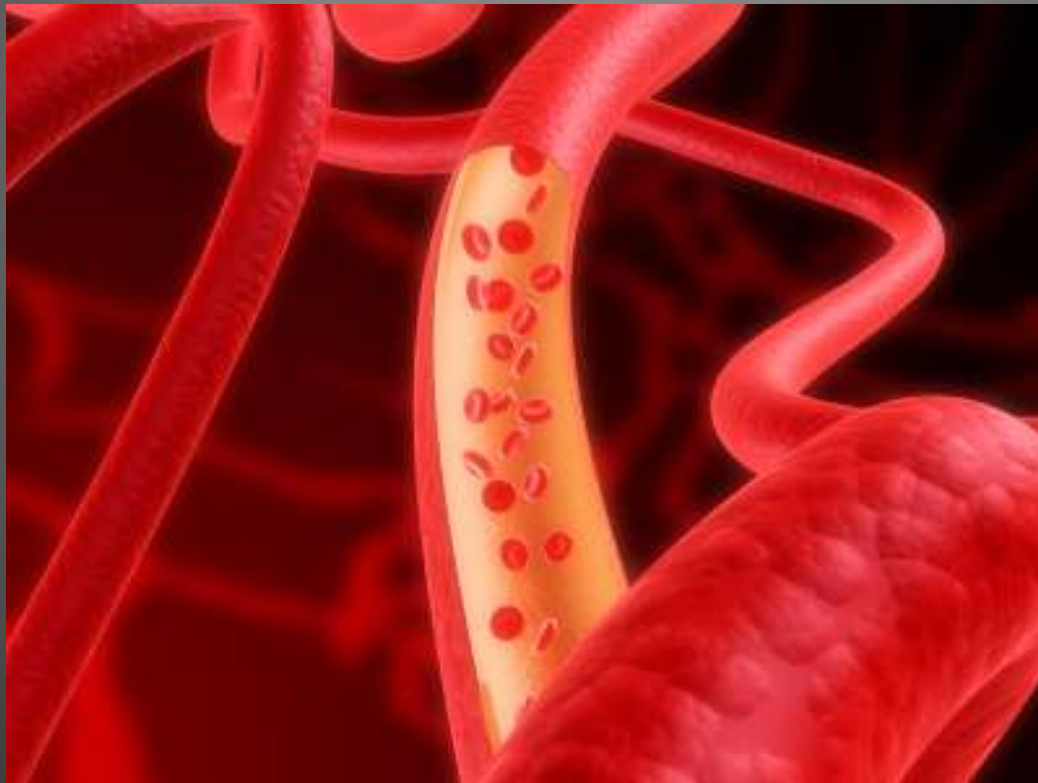
- Various hormones and ions have a dramatic effect on heart activity
- Epinephrine – mimics sympathetic nerves, increases heart rate
- Thyroxine – increase heart rate
- Electrolyte imbalance – prolonged contractions, arrhythmias, decrease output

Physical Factors

- Resting heart rate is fastest in the fetus and then gradually decreases
- Faster heart rate in females than males
- High body temperature also increase heart rate, Low body temperature decreases heart rate



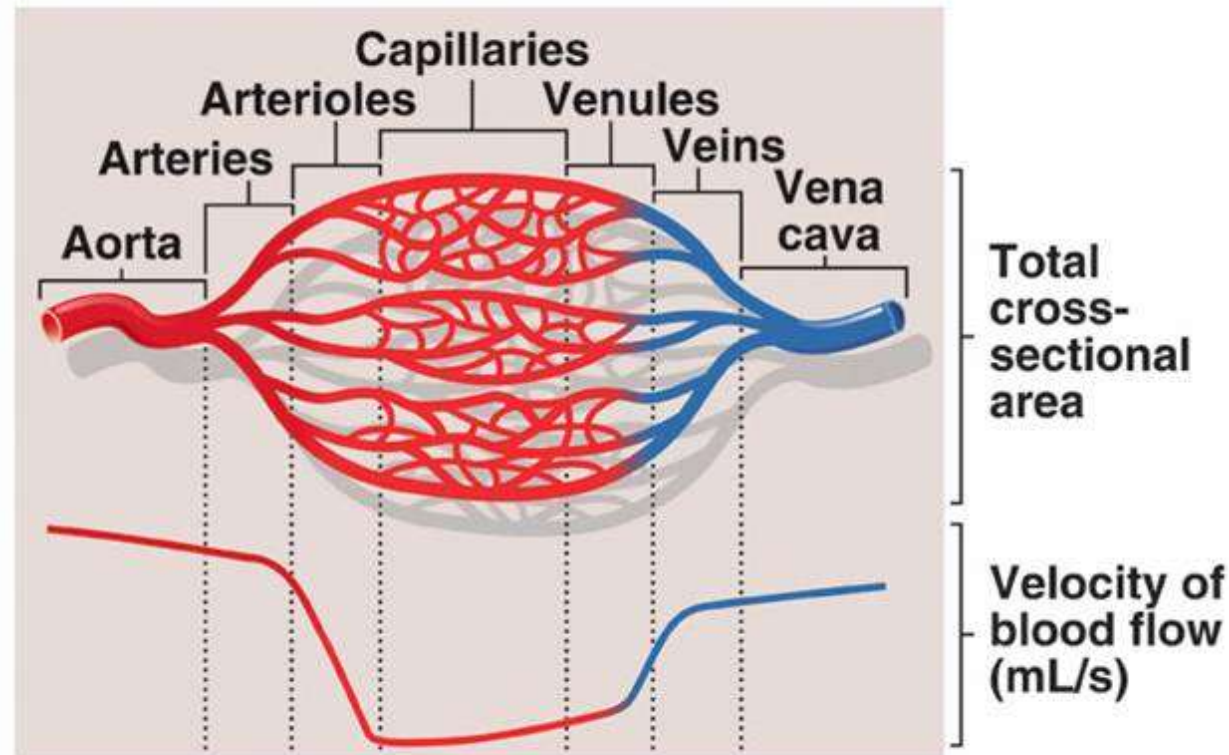
Blood Vessels



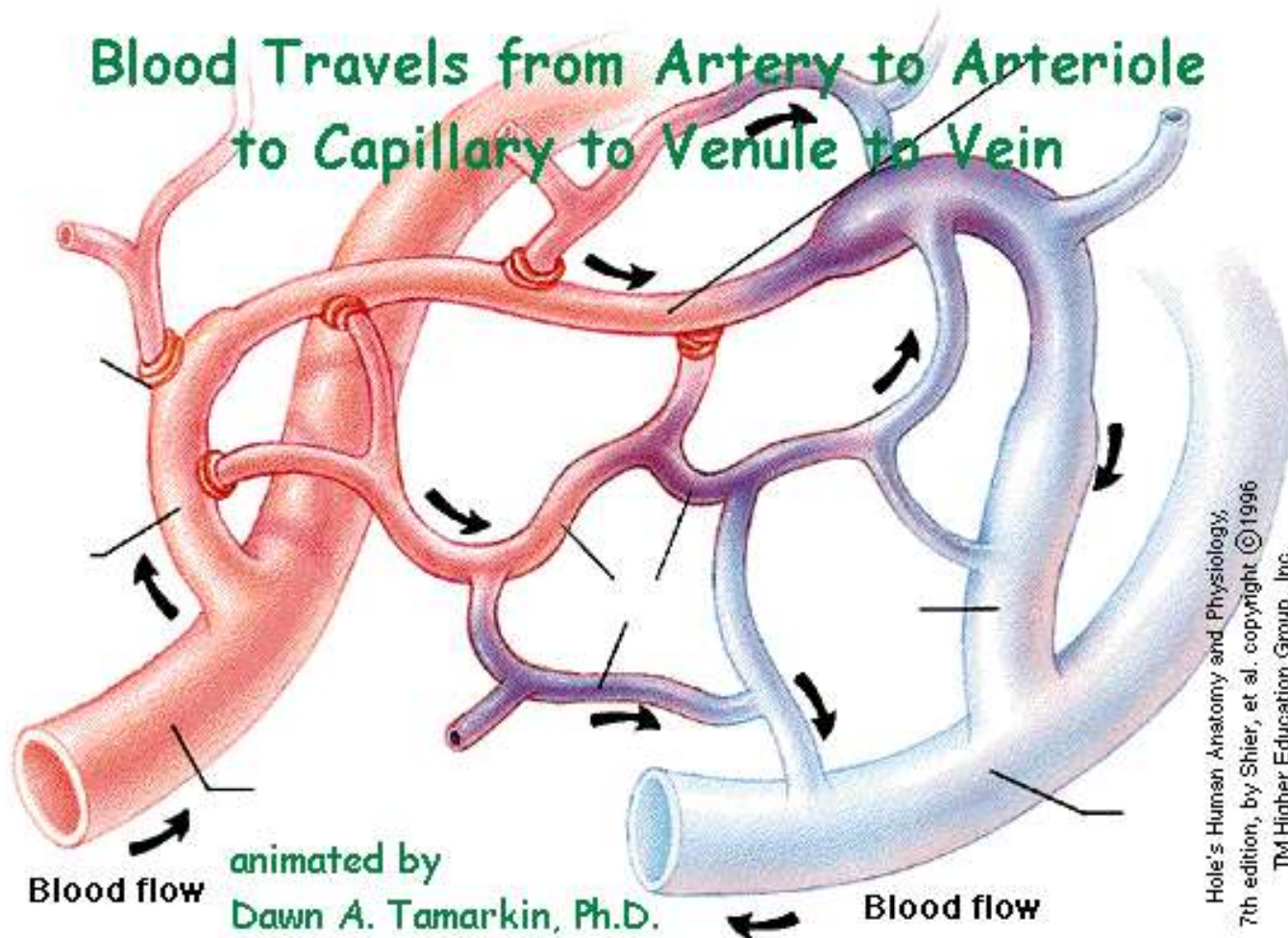
Blood Vessels

- Blood vessels create a closed transport system, or vascular system

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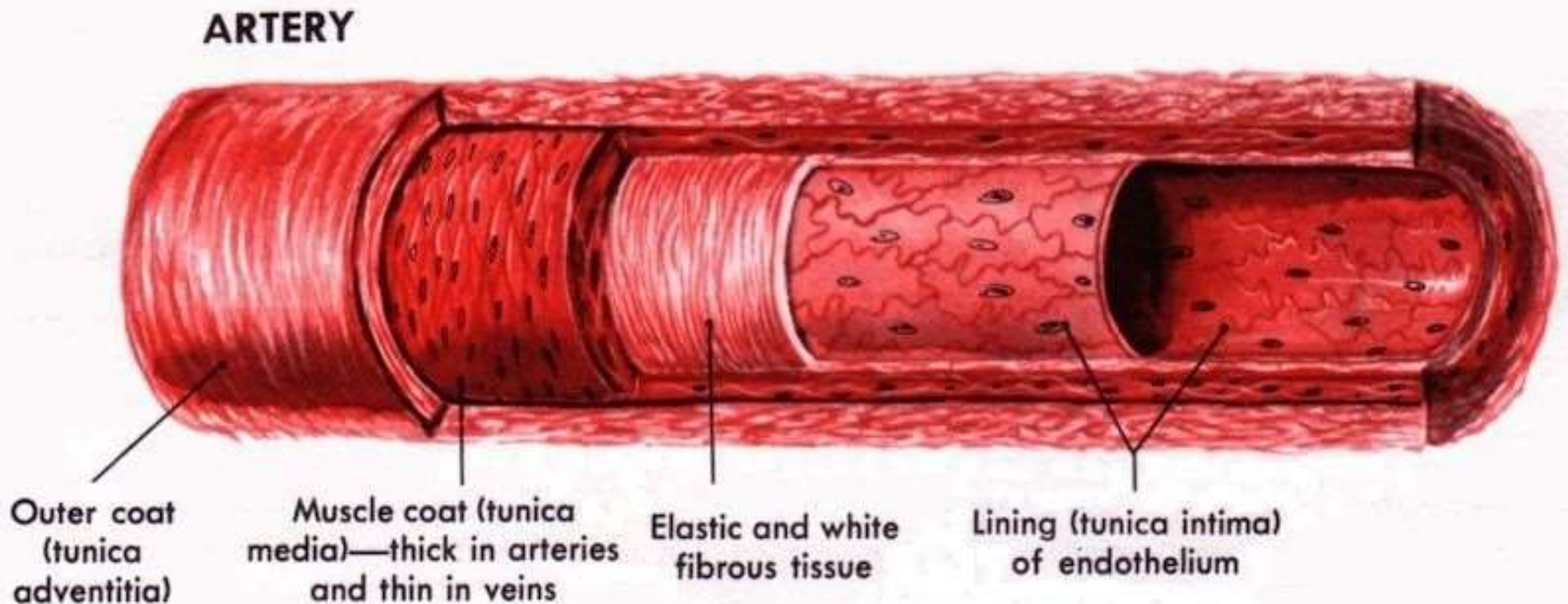


Blood Vessels

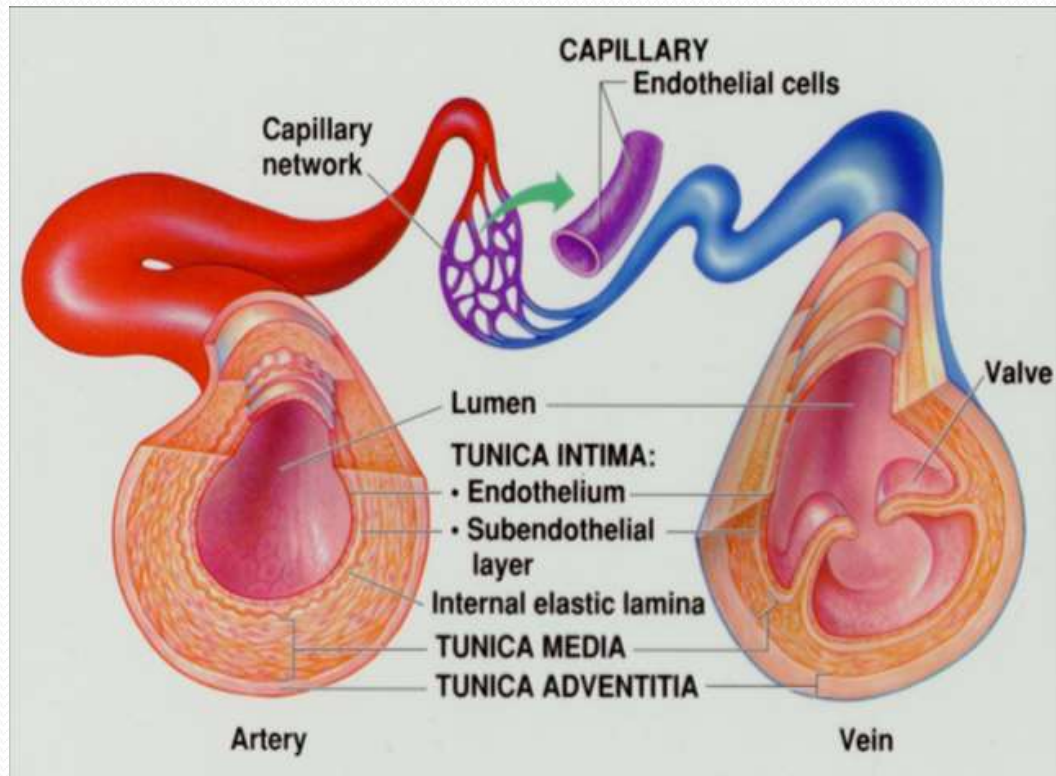


Blood Vessels - Arteries

- Arteries leave the heart
- Smaller arteries
- Arterioles



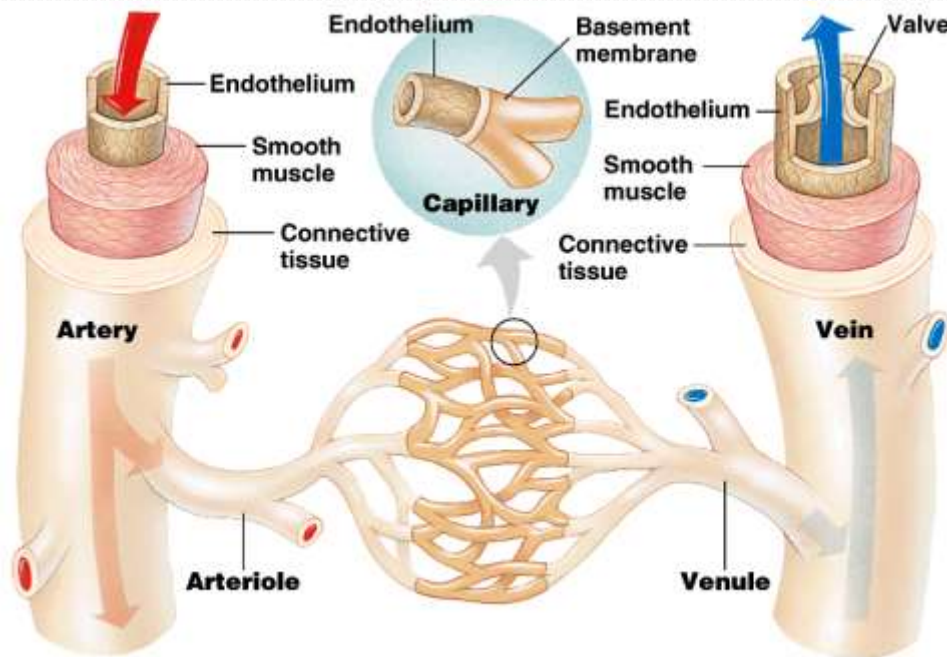
Blood Vessels - Arteries



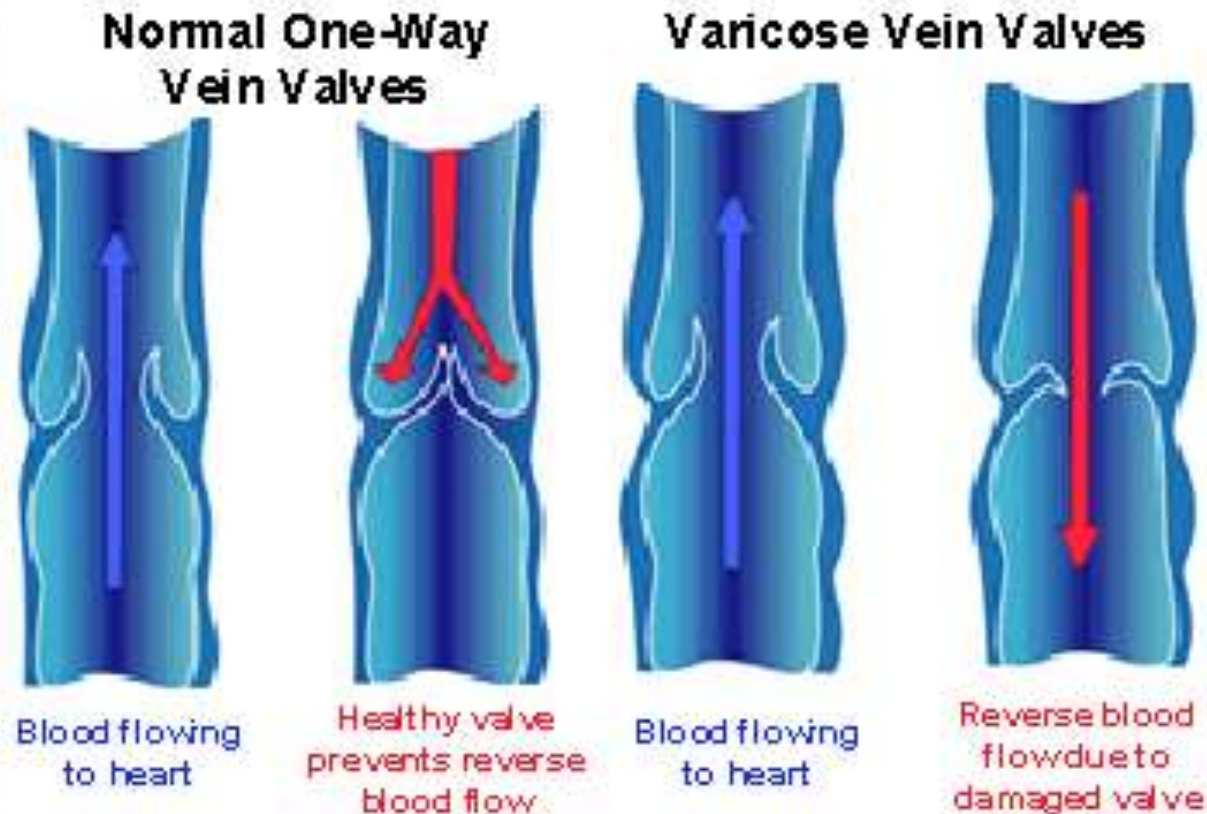
- Higher, changing blood pressure
- Thicker walls
- The middle section (tunica media) is especially thick
- Strong and stretchy

Blood Vessels - Capillaries

- Capillaries are minute blood vessels that connect arterioles and venules
- Form capillary beds



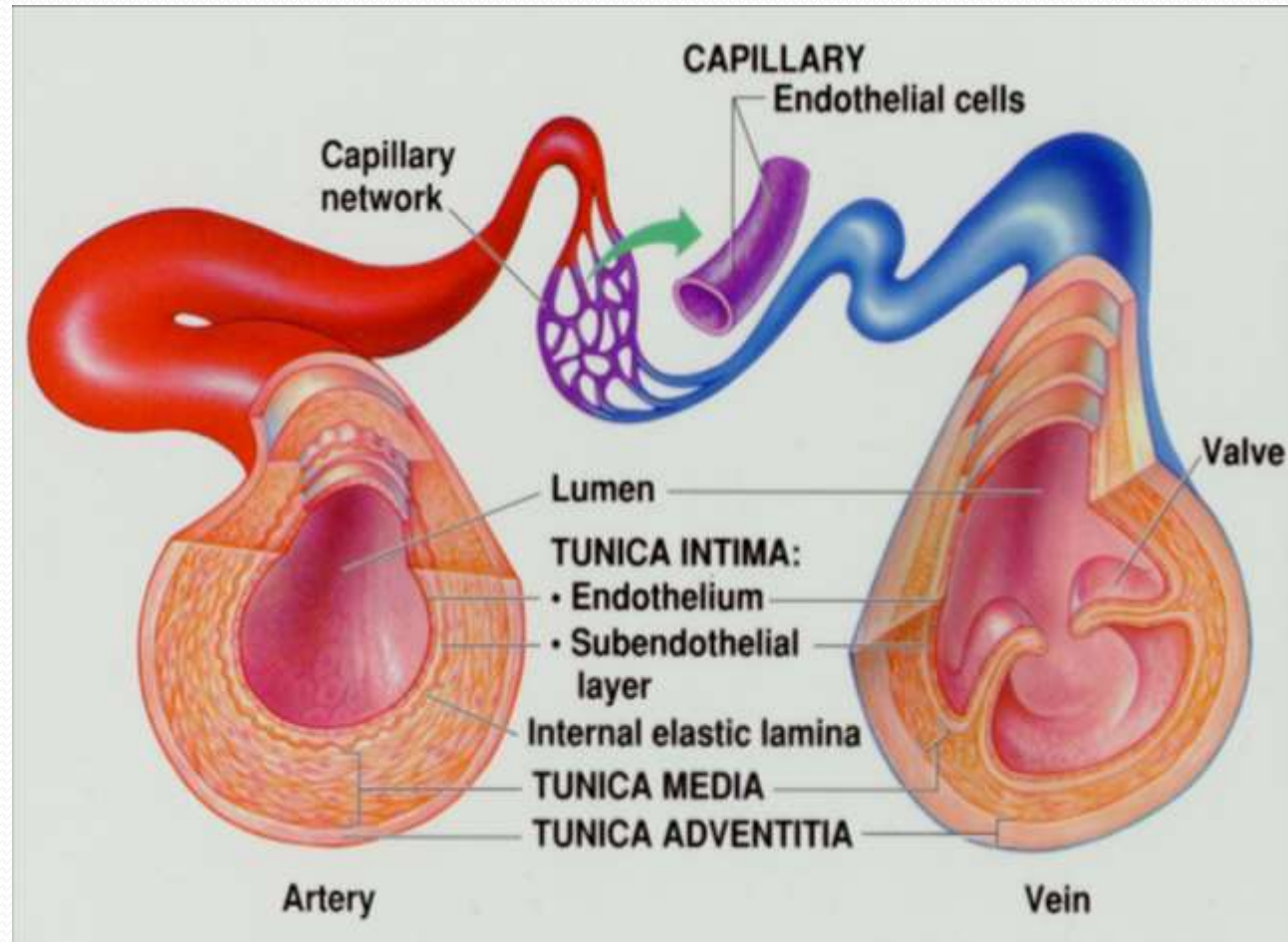
Blood Vessels - Veins



- Venules
- Larger veins
- Great veins (Vena cavae) return blood to the heart

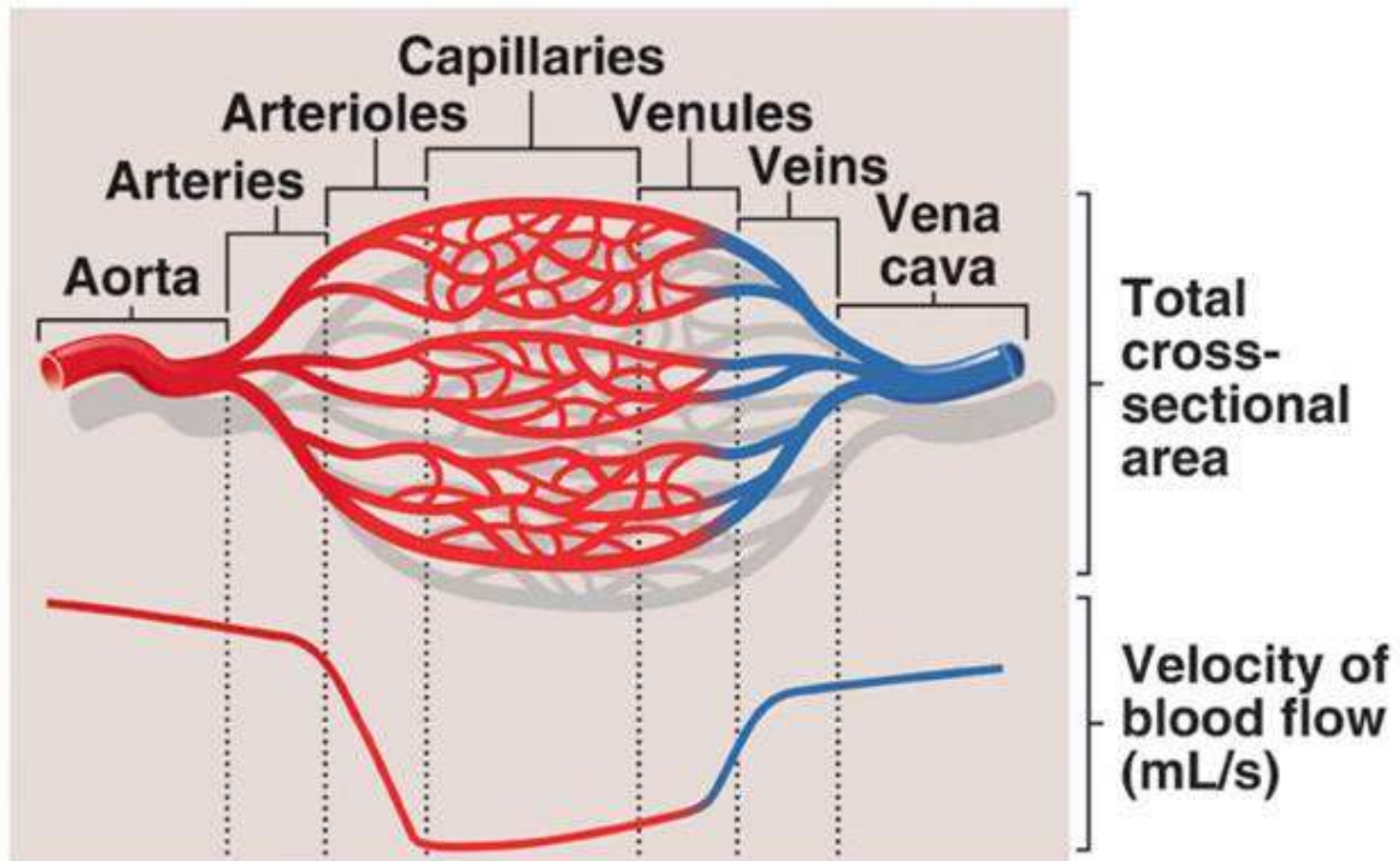
Blood Vessels - Veins

- Lower, constant blood pressure
- Thinner walls
- Blood often flows against gravity
- Have valves



Blood Vessels

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Blood Vessels

