

Unit 8



THE CARDIOVASCULAR SYSTEM

HEART FACTS

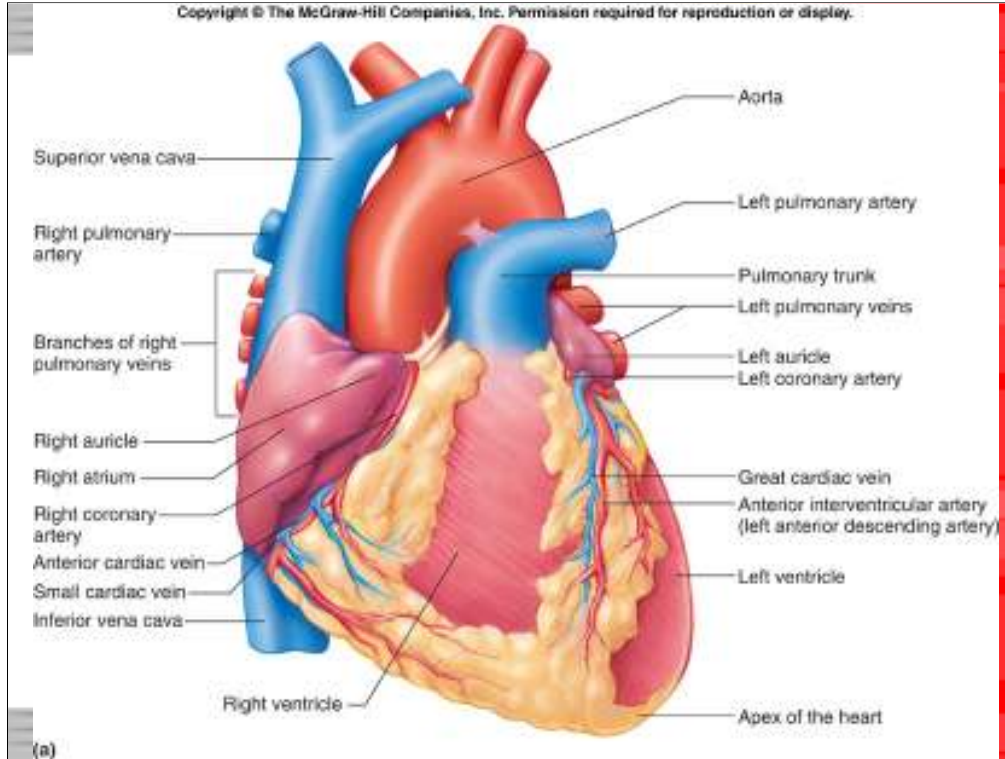
- **Put your hand on your heart. Did you place your hand on the left side of your chest? Many people do, but the heart is actually located almost in the center of the chest, between the lungs. It's tipped slightly so that a part of it sticks out and taps against the left side of the chest, which is what makes it seem as though it is located there.**
- **Hold out your hand and make a fist. If you're a kid, your heart is about the same size as your fist, and if you're an adult, it's about the same size as two fists.**
- **Your heart beats about 100,000 times in one day and about 35 million times in a year. During an average lifetime, the human heart will beat more than 2.5 billion times.**
- **Give a tennis ball a good, hard squeeze. You're using about the same amount of force your heart uses to pump blood out to the body. Even at rest, the muscles of the heart work hard--twice as hard as the leg muscles of a person sprinting.**
- **Feel your pulse by placing two fingers at pulse points on your neck or wrists. The pulse you feel is blood stopping and starting as it moves through your arteries. As a kid, your resting pulse might range from 90 to 120 beats per minute. As an adult, your pulse rate slows to an average of 72 beats per minute.**
- **The aorta, the largest artery in the body, is almost the diameter of a garden hose. Capillaries, on the other hand, are so small that it takes ten of them to equal the thickness of a human hair.**
- **Your body has about 5.6 liters (6 quarts) of blood. This 5.6 liters of blood circulates through the body three times every minute. In one day, the blood travels a total of 19,000 km (12,000 miles)--that's four times the distance across the US from coast to coast.**
- **The heart pumps about 1 million barrels of blood during an average lifetime--that's enough to fill more than 3 super tankers.**
- **lub-DUB, lub-DUB, lub-DUB. Sound familiar? If you listen to your heart beat, you'll hear two sounds. These "lub" and "DUB" sounds are made by the heart valves as they open and close. [See the valves in action.](#)**

Functions of the Heart

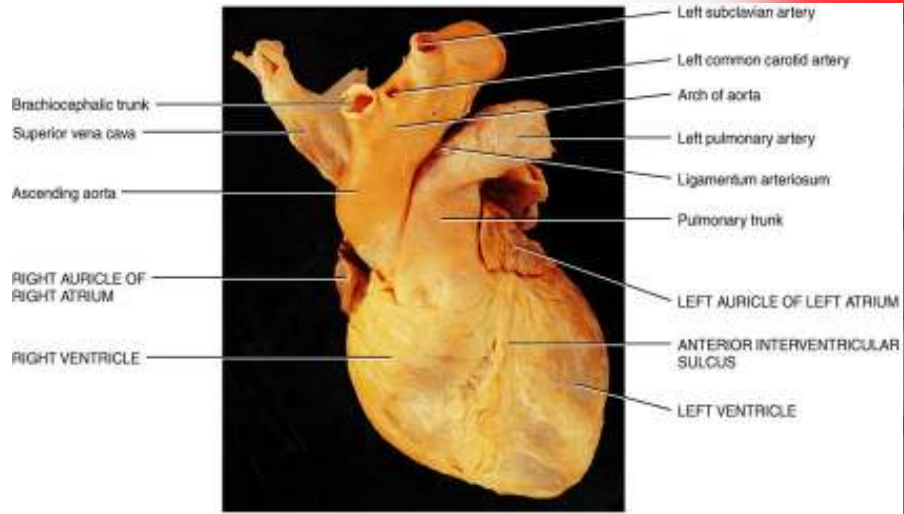
- PUMPS Blood
 - Transports Oxygen and Nutrients
 - Removes Carbon Dioxide and Metabolic Wastes
 - Thermoregulation
 - Immunological Function
 - Clotting Mechanisms

The Heart

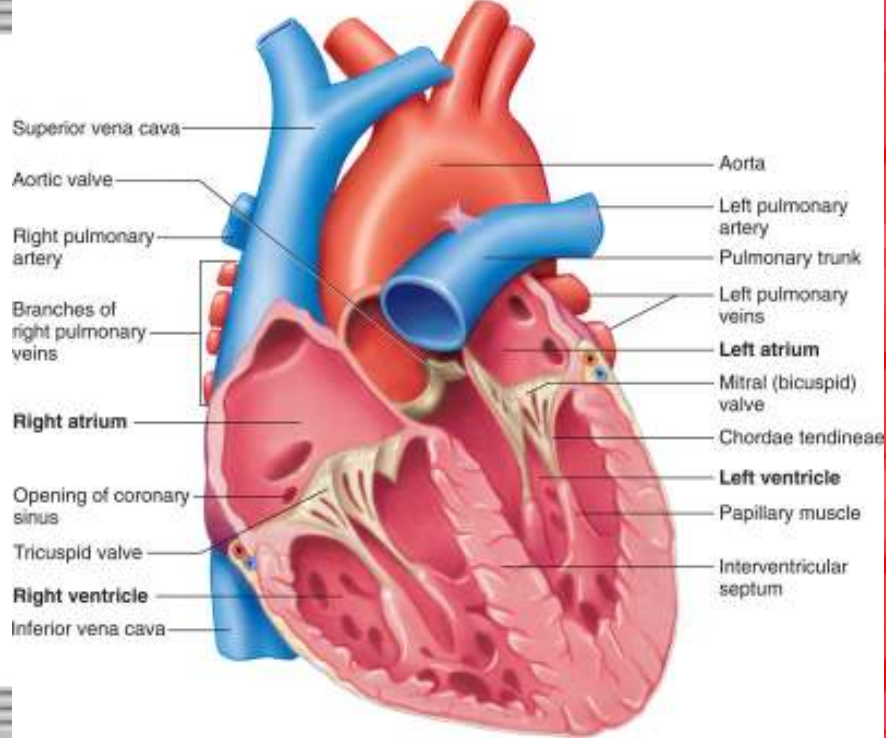
- Hollow, muscular organ
- Beats over 100,000 times a day
- Pumps 7,000 liters (1835 gallons) of blood per day
- Pumps blood through 60,000 miles of blood vessels in the circulatory system



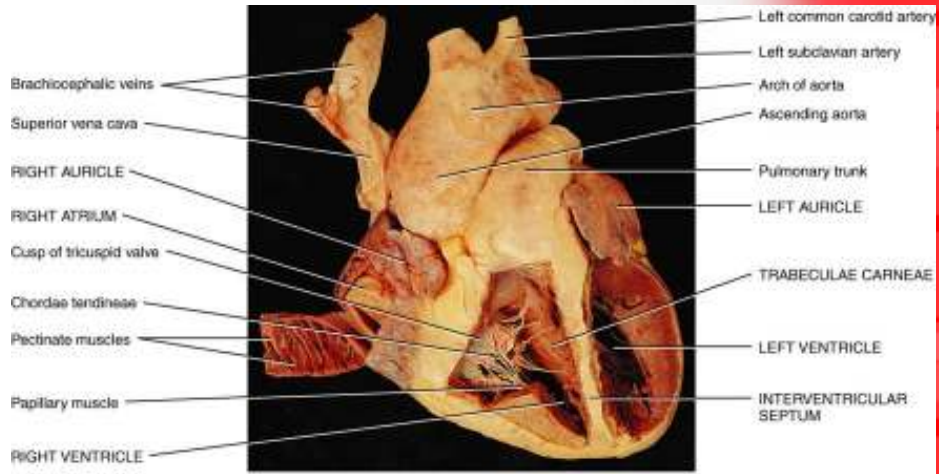
Heart Structures



(b) Anterior external view showing surface features
20.03b



Internal Cardiac Structures

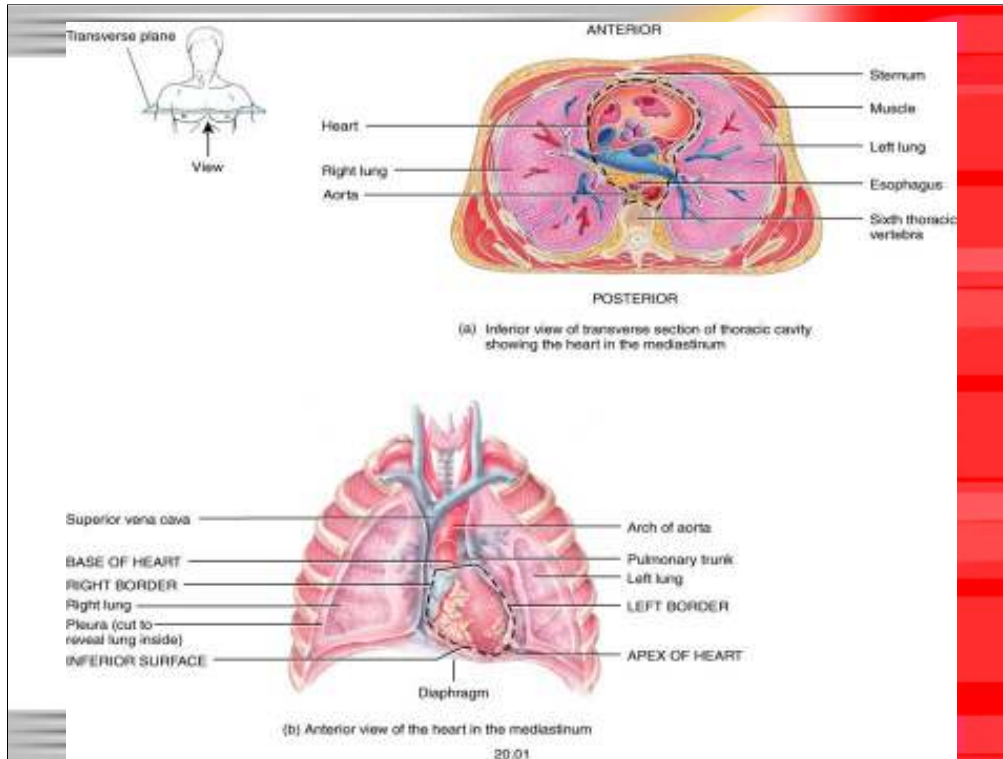


(b) Anterior view of partially sectioned heart showing internal anatomy

20.04b

Location of the Heart

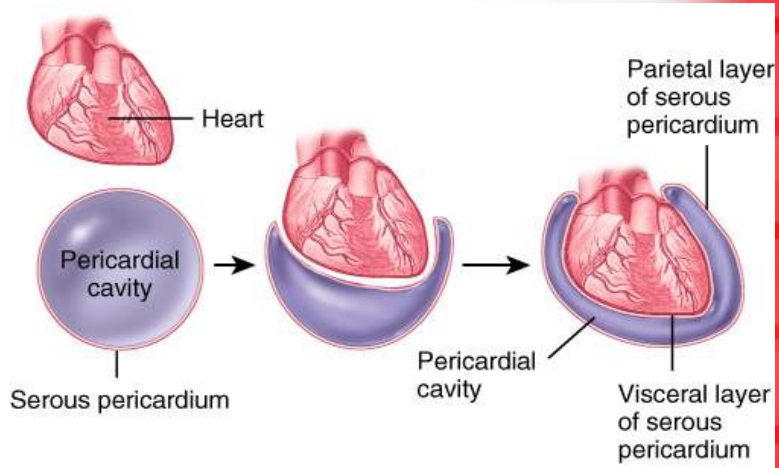
- Located in the center of the thoracic cavity (mediastinum) with 2/3 of the heart's mass lying to the left of the midline of the body
- About the size of your fist



Pericardium

- Fibrous connective tissue covering that surrounds the heart
- Fibrous Pericardium - outer layer of the pericardium
 - Anchors the heart to the mediastinum
- Serous Pericardium
 - Inner, thinner, more delicate double layered membrane surrounding the heart
 - Parietal Layer
 - Visceral Layer (Epicardium)

Pericardium



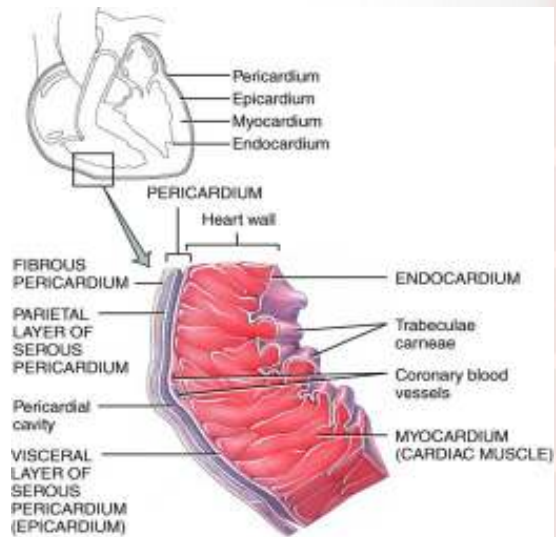
(b) Simplified relationship of the serous pericardium to the heart

20.02b

The Heart Wall

- Epicardium - the outermost layer of the heart wall (actually continuous with the visceral layer of the serous pericardium)
- Myocardium - middle layer of the heart muscle
 - Makes up the bulk of the heart muscle
- Endocardium - thin layer of endothelial connective tissue that lines the inside of the myocardium

Heart Tissue Layers



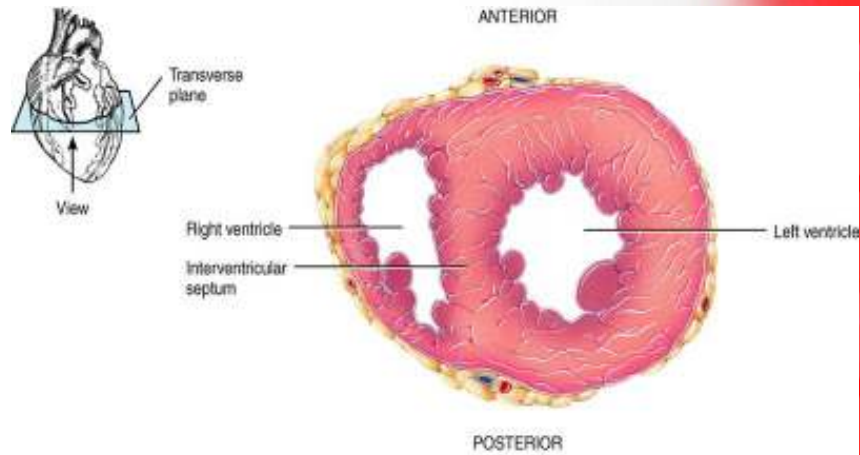
(a) Portion of pericardium and right ventricular heart wall showing the divisions of the pericardium and layers of the heart wall

20.02a

Chambers of the Heart

- Collecting Chambers
 - Atria
 - Right Atrium
 - Left Atrium
- Pumping Chambers
 - Ventricles
 - Right Ventricle
 - Left Ventricle

Ventricular Myocardium and Chambers



(c) Inferior view of transverse section showing differences in thickness of ventricular walls

20.04c

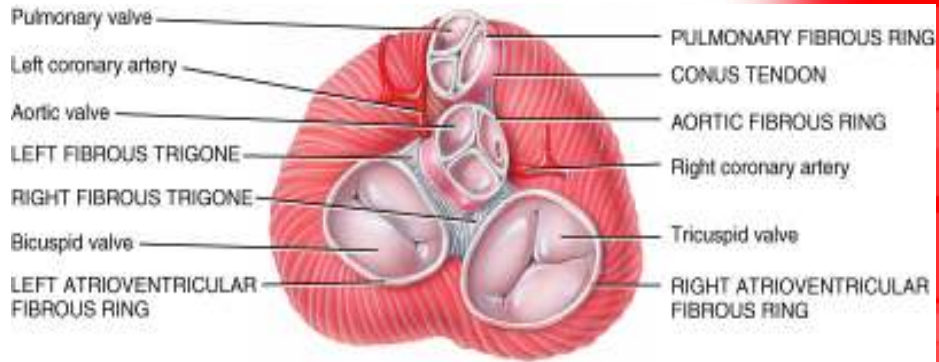
Vessels of the Heart

- Inferior Vena Cava
- Superior Vena Cava
- Pulmonary Artery
- Pulmonary Veins
- Aorta
 - Ascending Aorta
 - Arch of the Aorta
 - Descending Aorta

Heart Valves

- Atrioventricular Valves
 - Tricuspid Valve
 - Bicuspid Valve (Mitral Valve)
- Semilunar Valves
 - Pulmonary Semilunar Valve
 - Aortic Semilunar Valve

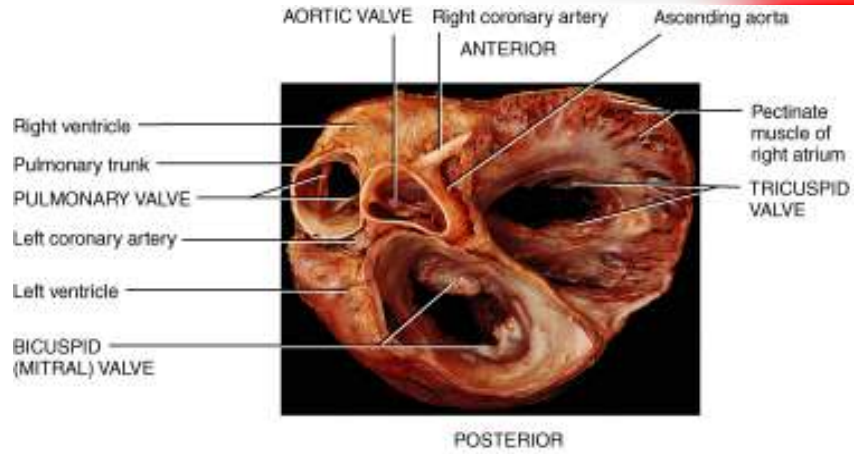
Heart Valves



Superior view (the atria have been removed)

20.05

Heart Valves



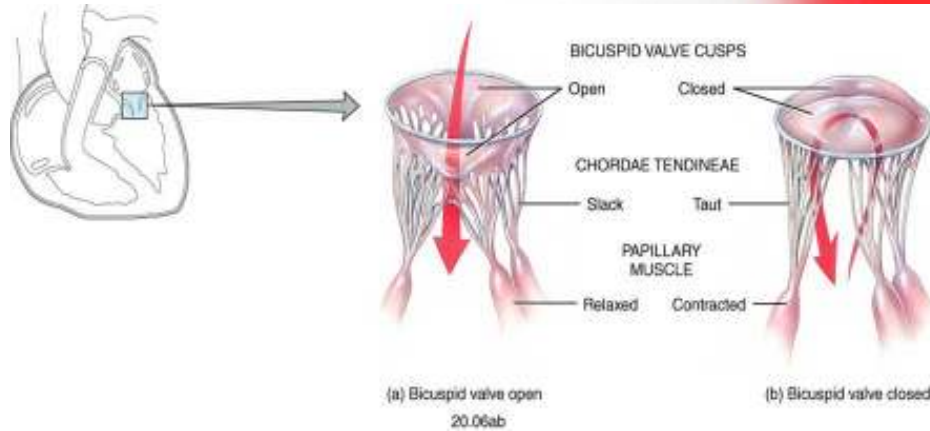
(e) Superior view of atrioventricular and semilunar valves

20.06a

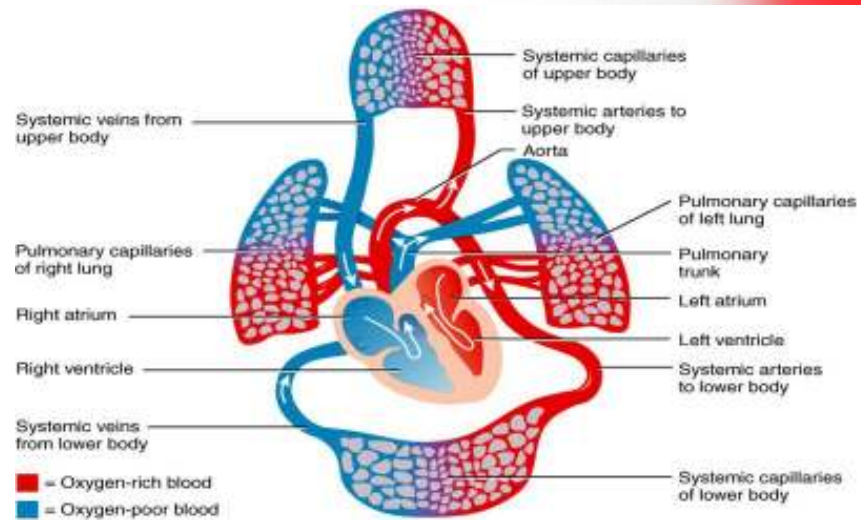
Internal Cardiac Structures

- Atrial Septum (Inter-Atrial Septum)
- Ventricular Septum (Inter-Ventricular Septum)
- Chordae Tendineae
- Papillary Muscles
- Trabeculae Carne

Atrioventricular Valves



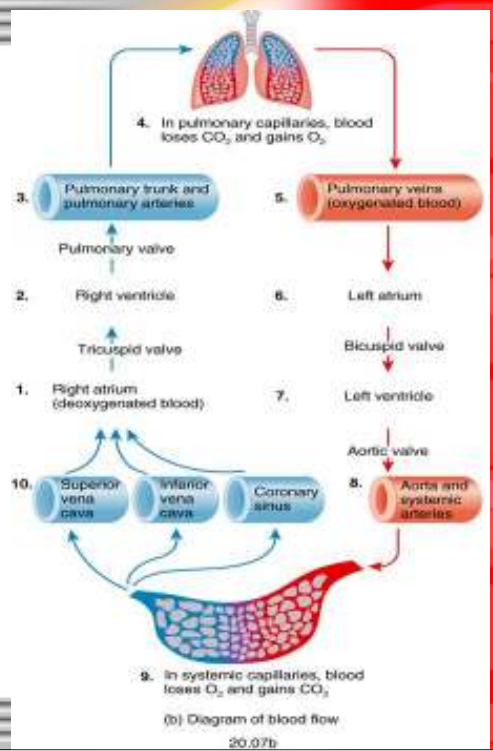
Circulation Pathways



(a) Systemic and pulmonary circulations

20.07a

Circulation Pathways



Visual Pathway of Blood through the Heart

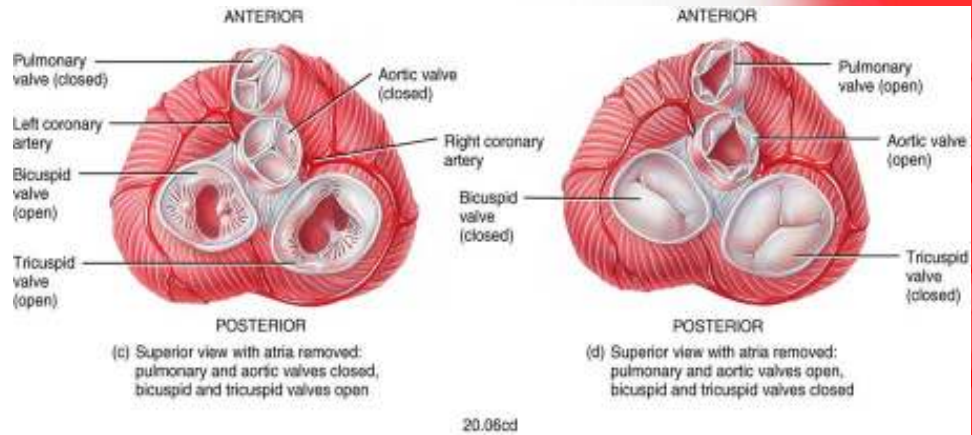
<http://www.lifebeatonline.com/winter2007/learning.shtml>

1. Oxygen-poor blood flows from the body into the right atrium.
2. Blood flows through the right atrium into the right ventricle.
3. The right ventricle pumps the blood to the lungs, where the blood releases waste gases and picks up oxygen.
4. The newly oxygen-rich blood returns to the heart and enters the left atrium.
5. Blood flows through the left atrium into the left ventricle.
6. The left ventricle pumps the oxygen-rich blood to all parts of the body.

13 - 25

Heart Valves

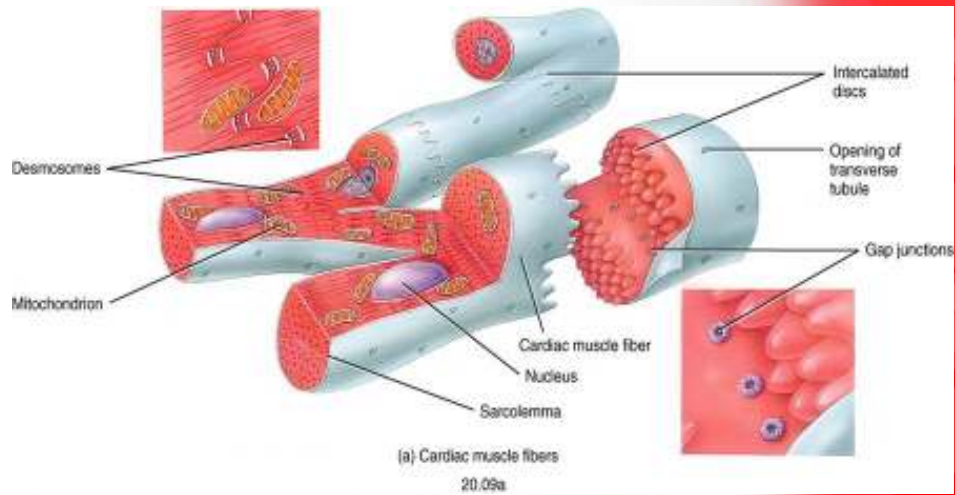
Opening and Closing



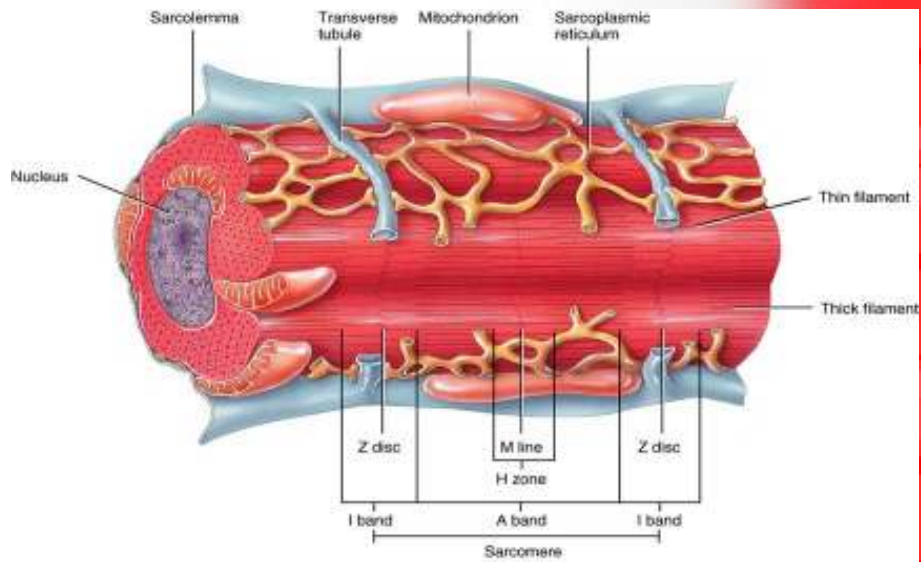
Conduction System of the Heart

- Self-Excitability - the ability to generate its own action potential (Autorhythmicity)
- Innervated by the autonomic nervous system
 - Influences heart rate
 - Does not initiate contraction
- Composed of specialized heart muscle cells that can generate and distribute impulses that causes contraction

Myocardial Cell Specialized Structures



Heart Muscle Cell

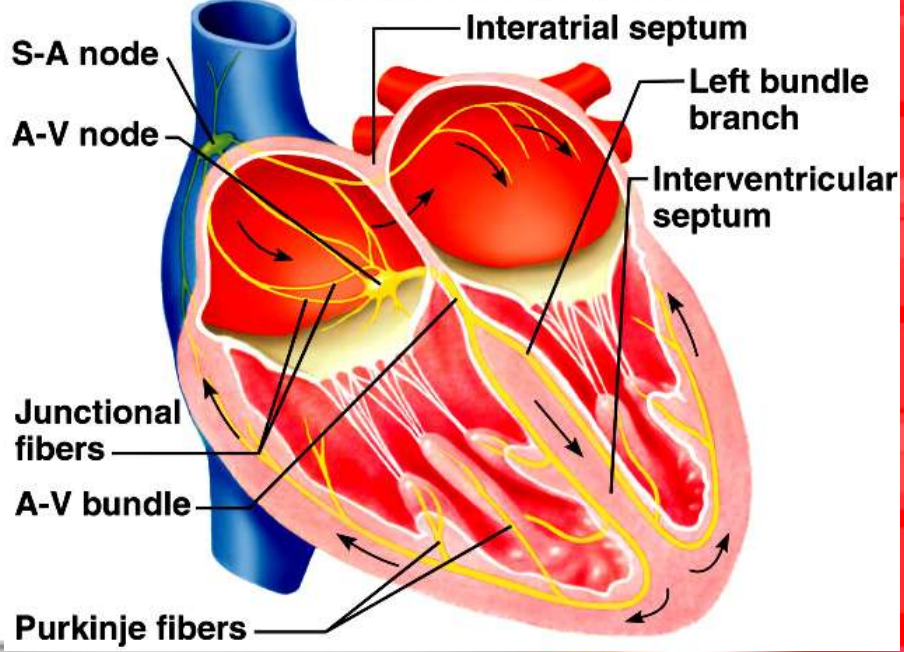


(b) Arrangement of components in a cardiac muscle fiber

20.09b

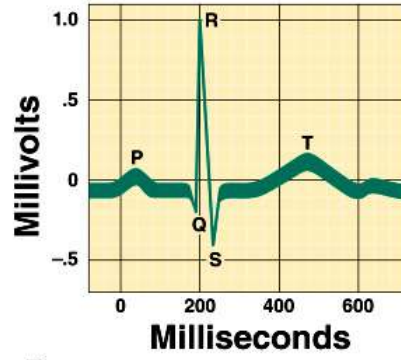
Heart Conduction System Structures

- SA Node (Sinoatrial Node)
 - Pacemaker of the Heart
 - Compact mass of specialized cells located in the right atrial wall just below the superior vena cava
- AV Node (Atrioventricular Node)
- Atrioventricular (AV) Bundle (Bundle of HIS)
- Right and Left Bundle Branches
- Purkinje Fibers





A



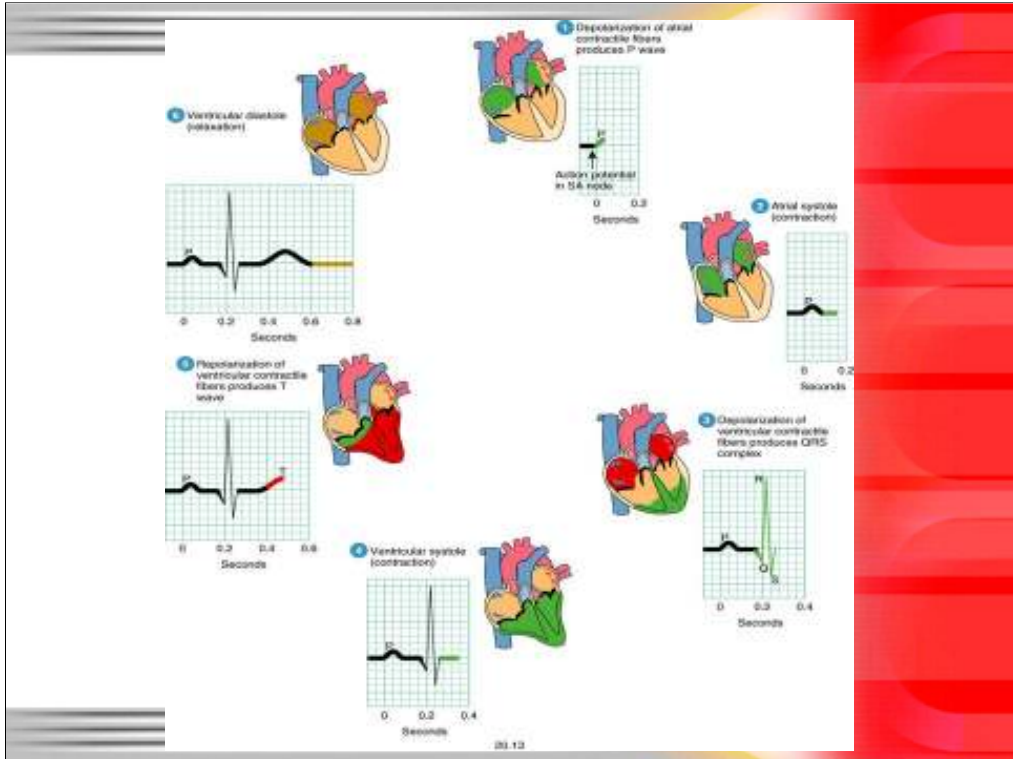
B

Electrocardiogram (EKG)

- Recordings of electrical changes that accompany a cardiac cycle
- P Wave - small upward deflection
 - Electrical Event - Atrial Depolarization
 - Mechanical Event - Atrial Contraction
- QRS Complex - small downward, large upward, large downward, and slight upward deflection on EKG
 - Electrical Event – Ventricular Depolarization
 - Mechanical Event - Ventricular Contraction

Electrocardiogram (EKG)

- T Wave - upward dome shaped deflection on the EKG
 - Electrical Event - Ventricular Repolarization
 - Mechanical Event - Ventricular Relaxation
- Atrial Repolarization
- Obscured by the QRS Complex
 - Occurs during the same time as ventricular contraction



The Cardiac Cycle

- All events associated with one heartbeat
- Normal cardiac cycle:
 - Two atria contract while the two ventricles relax
 - Two ventricles contract while the two atrias relax
- Systole - contraction phase
- Diastole - relaxation phase

Phases of the Cardiac Cycle

- EDV - End Diastolic Volume - the amount of blood that enters a heart ventricle from the atria during diastole (relaxation of the ventricles)
- Ventricular Systole - contraction of the ventricles
 - Isovolumetric Contraction - a brief period of time when the ventricles are contracting but both the atrioventricular and semilunar valves remain closed

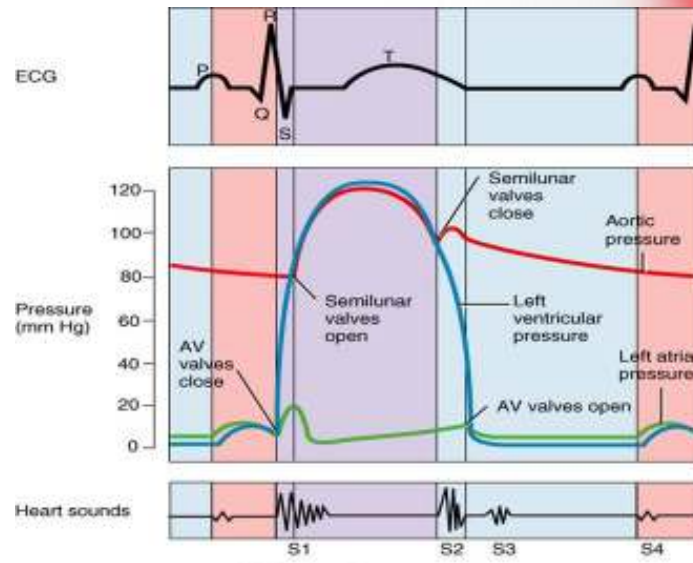
Phases of the Cardiac Cycle

- Relaxation Period - the end of the heartbeat when the ventricles are starting to relax
 - Isovolumetric Relaxation - the short period of time in which both the atrioventricular and semilunar valves are closed
- Ventricular Filling - period of time when the ventricles are filling with blood and expanding

Phases of the Cardiac Cycle

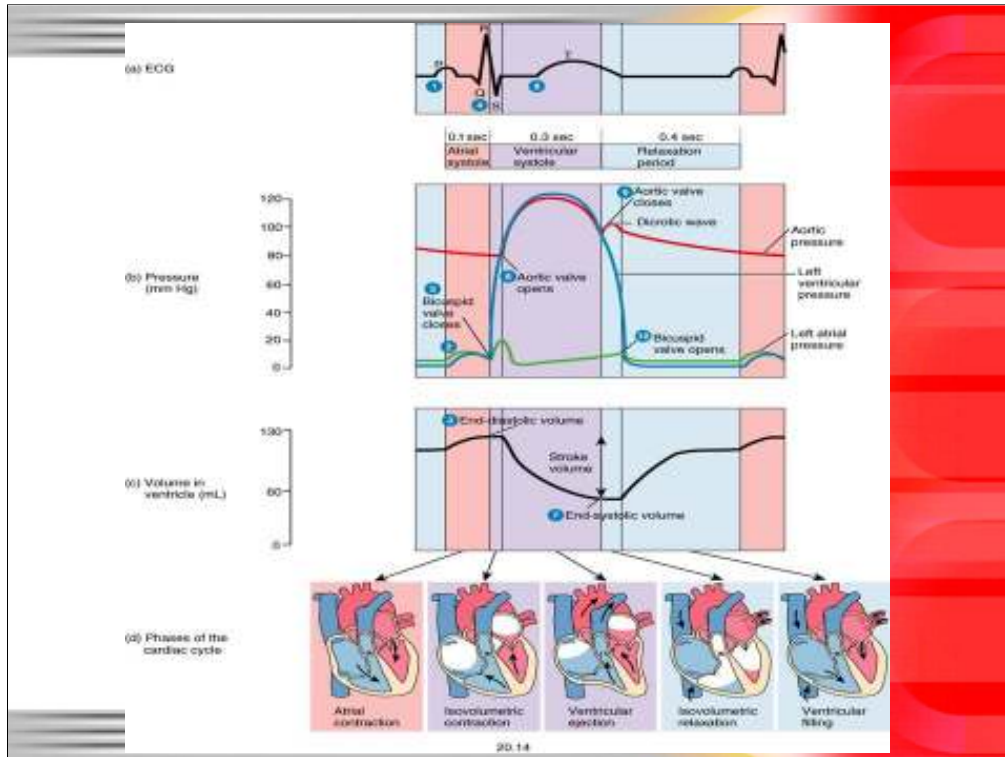
- ESV - End Systolic Volume - the amount of blood still left in the ventricle after systole (contraction of the ventricles)
- Stroke Volume - the amount of blood ejected from the left ventricle during each heartbeat (systole) $EDV - ESV = SV$
- Heart Rate - the number of times the heart beats or completes a full cycle of events each minute
 - normally 60 - 100 beats per minute

Wigger's Diagram



(a) Timing of heart sounds

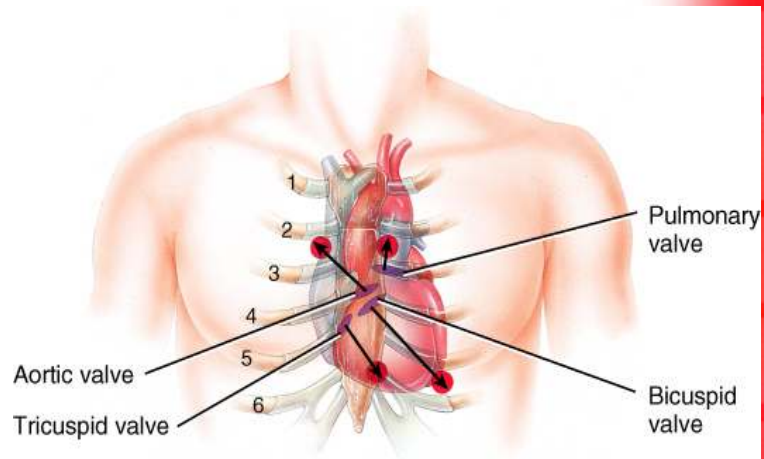
20.15a



Heart Sounds

- Auscultation - the process of listening for sounds
- Heart makes 4 sounds - 2 of which can be heard with a stethoscope
- Lubb - sound generated by blood swirling or turbulence after closing of the Atrioventricular valves
- Dupp - sound generated by blood swirling or turbulence after closing of the Semilunar valves

Heart Auscultation Sites



(b) Anterior view of heart valve locations and auscultation sites

20.15b

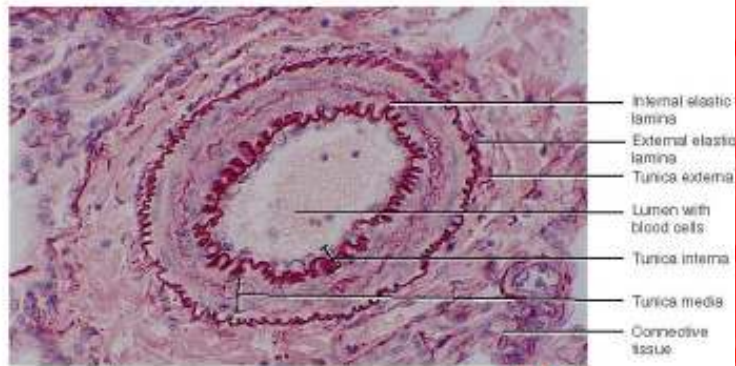
Cardiac Output

- Measurement that indicates how well and how hard the heart is working
- The amount of blood pumped out of the left ventricle each minute
- Function of heart rate X stroke volume
- $CO = HR \times SV$
 - Resting C.O. is about 5 liters per minute
 - $75 \text{ bpm} \times 70 \text{ ml/beat} = 5250 \text{ ml/min}$
 - During strenuous exercise can have a C.O. of between 25 to 30 Liters per minute

Blood Vessels

- Aorta
- Arteries
- Arterioles
- Capillaries
- Venules
- Veins
- Superior and Inferior Vena Cava

Blood Vessels



(d) Transverse section through an artery

LM 200x



(e) Red blood cells passing through a capillary

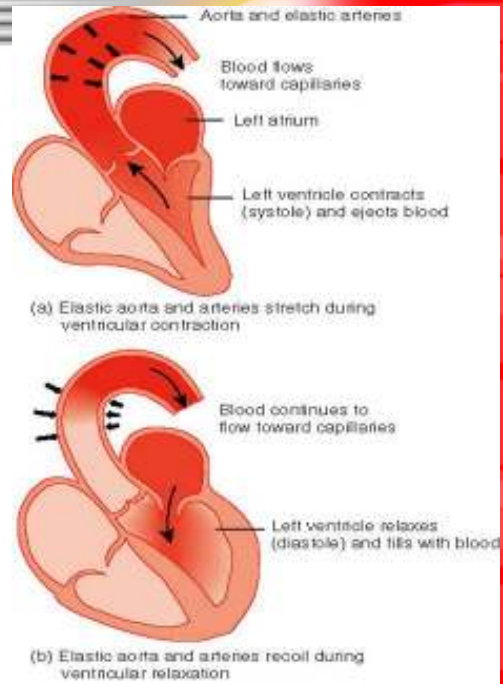
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Arteries

- Blood vessels that carry blood away from the heart and to other tissues
- Lumen - the hollow center section of an artery through which the blood flows
- Elastic Arteries
 - Large arteries that conduct blood from the heart to the medium sized muscular arteries
- Muscular (Distributing) Arteries
 - Medium sized arteries that distribute blood to various parts of the body

Elastic Arteries

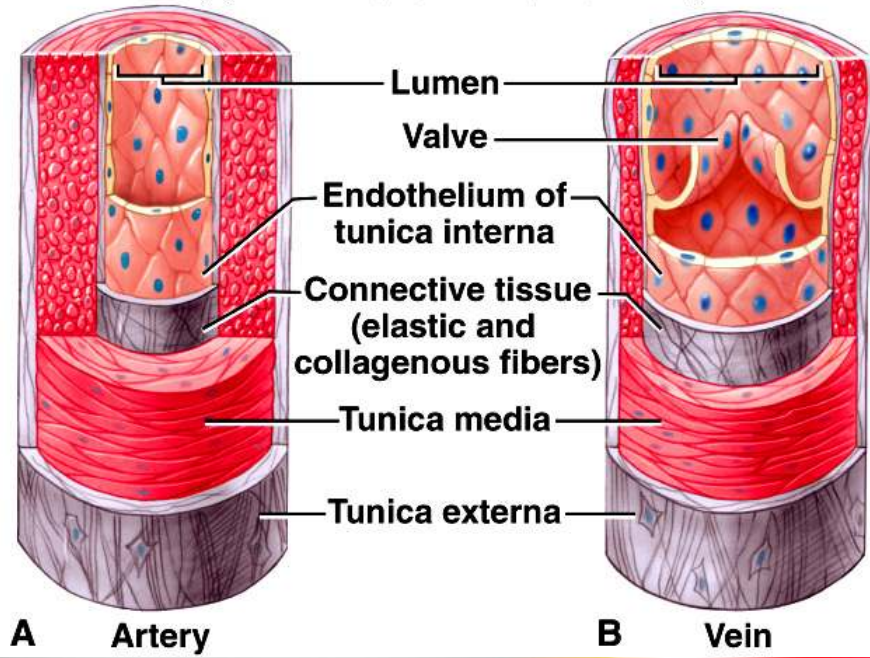
- Windkessel Vessels



21.02

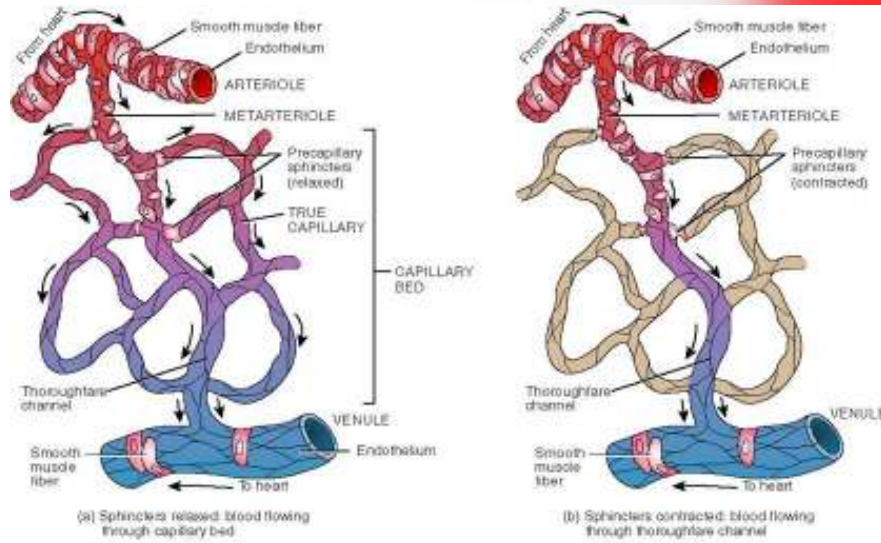
Tissue Layers of Arteries

- Tunica Interna (Intima) - the inner lining of an artery
 - Made up of endothelial tissue
- Tunica Media - the middle layer of tissue in an artery
 - Usually the thickest layer of tissue
 - Made up of elastic fibers and smooth muscle tissue
- Tunica Externa (Adventitia) - the outermost layer of an artery
 - Made up of elastic and collagen fibers



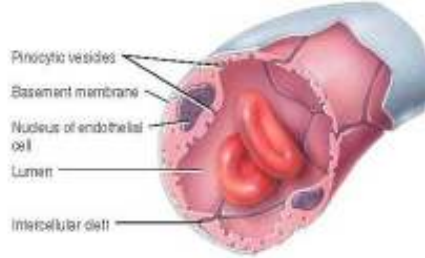
- Arterioles - small, almost microscopic arteries that deliver blood to capillaries
- Capillaries - microscopic vessels that connect arterioles to venules
 - Found close to almost every cell in the body
 - Supplies nutrients and oxygen to tissues
 - Removes metabolic waste products from tissues
 - Composed of a single layer of tissue with no tunica media or tunica externa
 - Single layer of endothelial cells and a basement membrane

Capillary Beds

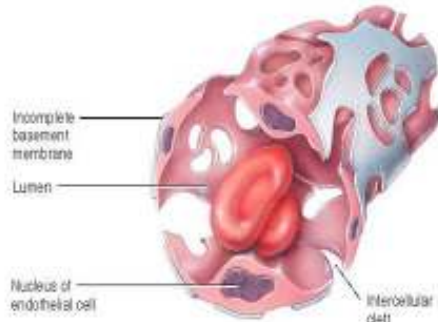


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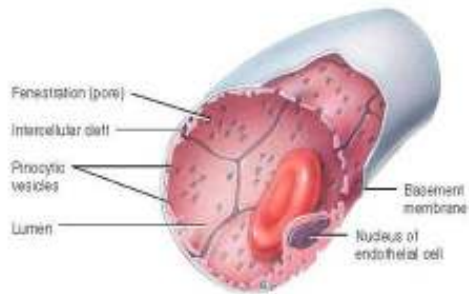
Types of Capillaries



(a) Continuous capillary formed by endothelial cells



(c) Sinusoid



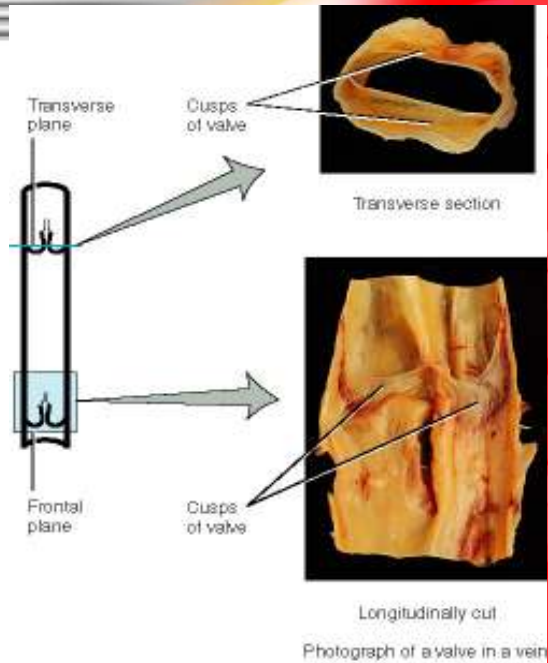
(b) Fenestrated capillary

21.04

- Venules - microscopic blood vessels that leave the capillaries and drain into veins
- Veins - blood vessels that return blood from body tissues to the heart
 - Same three layers of tissues as arteries
 - Vary in thickness much more than arteries
 - Have one-way valves in them to prevent back flow of blood

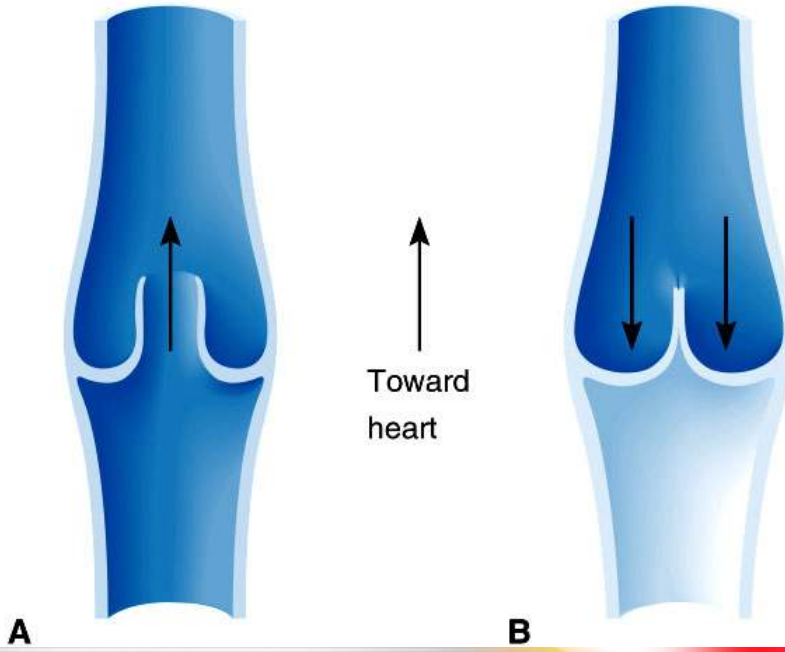
Veins

- Valves to direct blood flow back toward the heart



21.05

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Venous Return

- Volume of blood flowing back to the heart from the systemic veins
- Pressure Difference between the right atrium and the venous system
- Skeletal Muscle Pump (Milking)
 - the contraction of skeletal muscles forces the blood in the veins of those muscles back toward the heart
- Respiratory Pump - changes in the volumes and pressures of the abdominal and thoracic cavity during breathing forces blood back to the heart

Skeletal Muscle Pump



21.06

Carotid Pulse



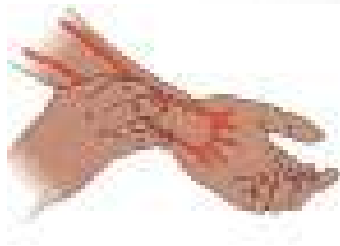
21.T02A-Hc

Brachial Pulse



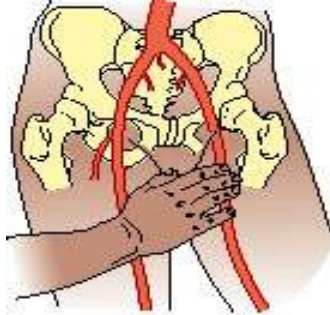
21.T02A-Hd

Radial Pulse



21.T02A-Hg

Femoral Pulse



21.T02A-He

Popliteal Pulse



21.T02A-Hf

Dorsal Pedalis Pulse

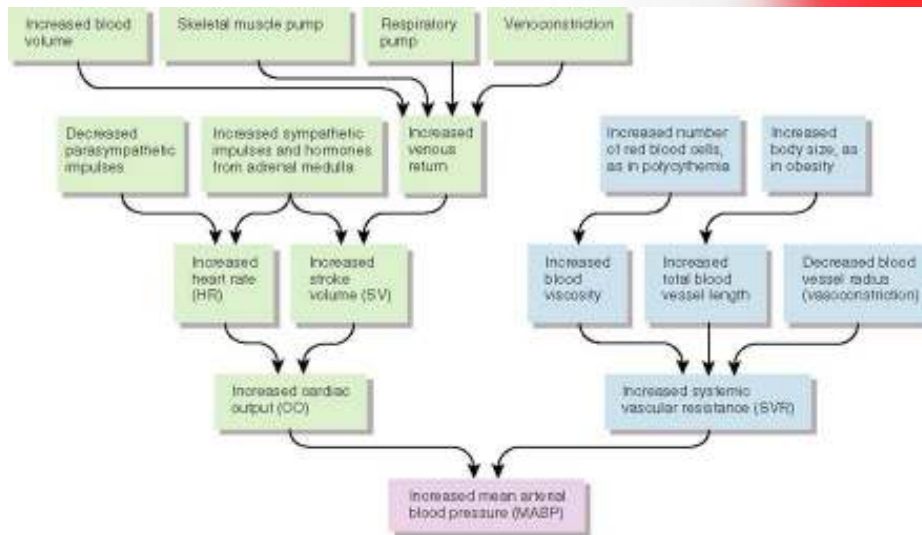


21.T02A-Hh

Factors Influencing Blood Pressure

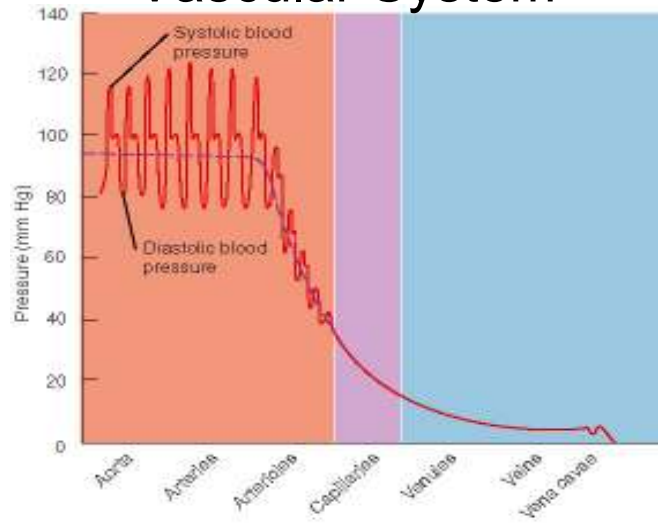
- $BP = C.O. \times TPR$
 - C.O. - Cardiac Output
 - HR (Heart Rate)
 - SV (Stroke Volume)
 - TPR - Total Peripheral Resistance
 - Blood Vessel Diameter
 - Vasoconstriction
 - Vasodilation
 - Blood Vessel Length
 - Blood Viscosity

Influence of Blood Pressure



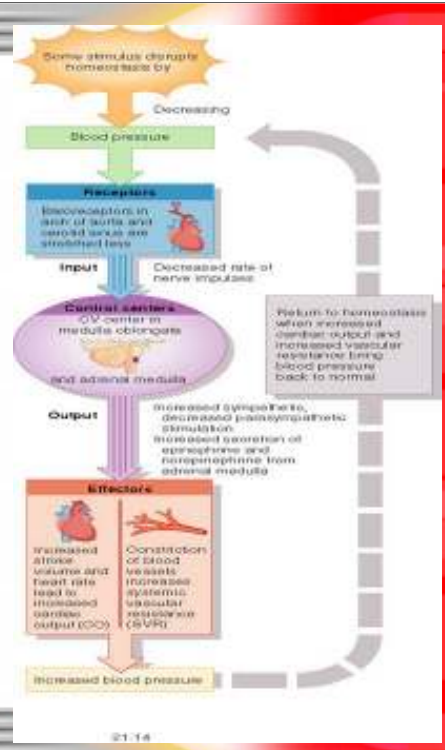
21.10

Blood Pressure through the Vascular System



21.08

Homeostasis and blood pressure regulation

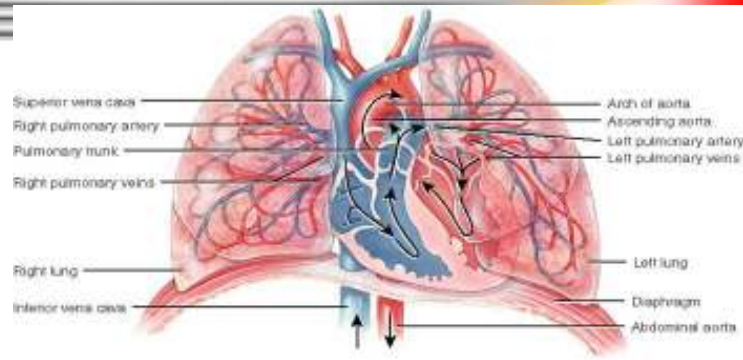


Factors Effecting Blood Flow

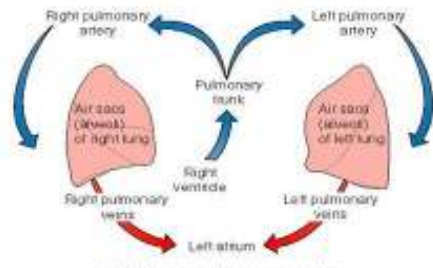
- Cardiac Output - $HR \times SV$
- Blood Pressure - the pressure exerted by blood on the walls of blood vessels
- TPR - Total Peripheral Resistance
 - opposition to blood flow through the vessels due to friction between the blood and the vessel walls
 - blood viscosity
 - total blood vessel length (1 mile per pound)
 - radius of blood vessel
- Capillary Exchange - exchange of substances between the blood and cells

Pulmonary Circulation

- All the circulatory vessels that carry deoxygenated blood from the right ventricle, to the lungs for re-oxygenation, and back to the left atrium of the heart.



(a) Anterior view

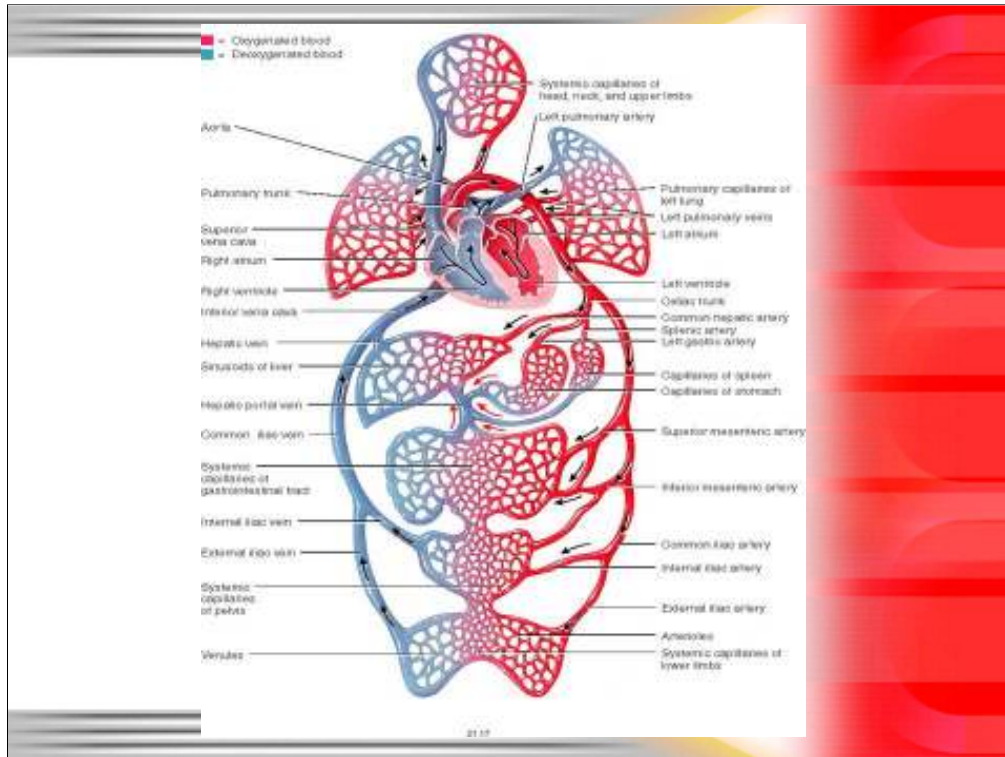


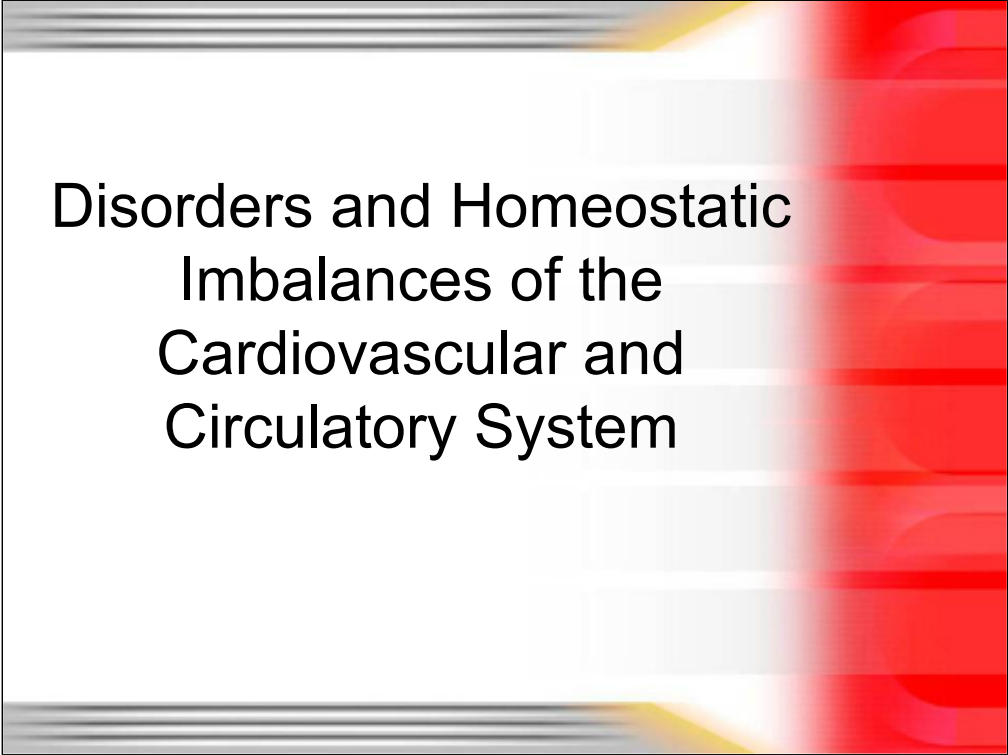
(b) Scheme of pulmonary circulation

21.25

Systemic Circulation

- Circulatory routes of arteries and arterioles that carry oxygenated blood from the left ventricle to the systemic capillaries of the body's organs and return deoxygenated blood back to the right atrium through the venules and veins





Disorders and Homeostatic Imbalances of the Cardiovascular and Circulatory System

Aneurysm

- A weakening in the wall of an artery or vein that can bulge outward or herniate
- Caused by atherosclerosis, syphilis, congenital vessel defects, and trauma
- If untreated may eventually grow large and rupture causing severe pain, shock, and eventually death
- Can be repaired surgically by inserting a dacron graft over the weakened area

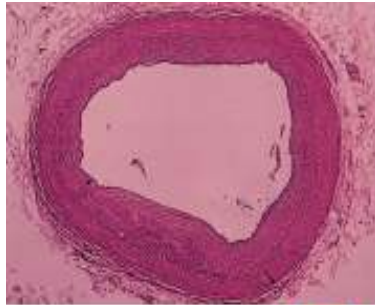
Arteriosclerosis

- Hardening of the arteries related to age and other disease processes.

Atherosclerosis

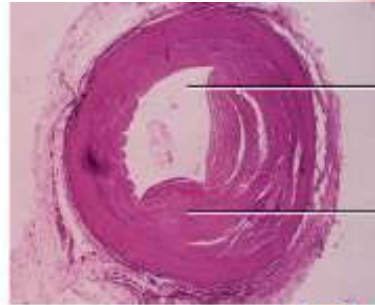
- The process by which fatty deposits (usually plaque) are deposited on the walls of the coronary arteries
- Usually enhanced by diets high in saturated fats and cholesterol

Atherosclerosis



LM 20x

(a) Normal artery



LM 20x

(b) Obstructed artery

Partially
obstructed
lumen (space
through which
blood flows)
Atherosclerotic
plaque

20.19

Cerebral Vascular Accident (CVA) - Stroke

- A general term most commonly applied to cerebral vascular conditions that accompany either ischemic or hemorrhagic lesions.
- These conditions are usually secondary to atherosclerotic disease, hypertension, or a combination of both.

Coronary Artery Disease

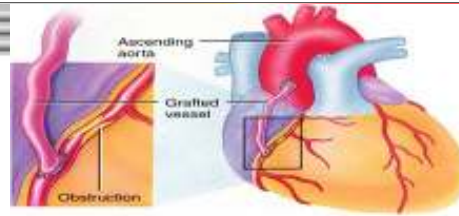
- #1 cause of death for middle aged men and post menopausal women in the United States
- Over 500,000 deaths annually
- Heart muscle receives inadequate blood and oxygen because of occlusion of coronary arteries

Etiology of CAD

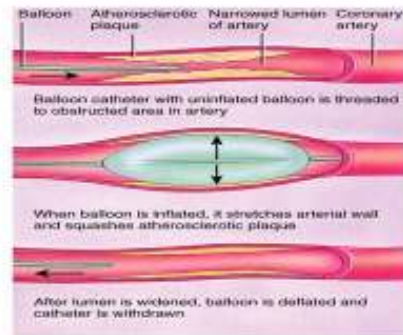
- Cardiovascular Disease Risk Factors
- Lesion Develops
 - Smoking -Hypertension -Diabetes
- Plaque Build Up ---->Atherosclerosis
 - accelerated by Hyperlipidemia
- Occlusion of Coronary Artery
- Ischemia
- Hypoxia
- Necrosis
- Myocardial Infarction (M.I.)

CAD Interventions

- CABG
 - Coronary
 - Artery
 - Bypass
 - Graft
- PTCA
 - Percutaneous
 - Transluminal
 - Coronary
 - Angioplasty
- Stent
- Drug Therapy



(a) Coronary artery bypass grafting (CABG)



(b) Percutaneous transluminal coronary angioplasty (PTCA)



(c) Stent in an artery

20.20

Cardiovascular Disease Risk Factors

- Uncontrollable Risk Factors
 - Age - Gender - Heredity - Race
- Primary Risk Factors
 - Smoking - Lack of Exercise
 - Hypertension - Hyperlipidemia
 - Diabetes - Obesity
- Secondary (Contributing) Risk Factors
 - Stress - Nutritional Status

Hypertension

- High blood pressure
- Can lead to:
 - Stroke
 - CAD - atherosclerosis
 - cardiomegaly - cardiomyopathy
 - Congestive Heart Failure (CHF)

Determination of Hypertension

- Diastolic Pressure
 - Mild 90 - 104 mm Hg
 - Moderate 105 - 114 mm Hg
 - Severe > 115 mm Hg
- Systolic Pressure - not usually related to hypertension unless systolic reading is consistently above 140 mm Hg

Classification of Hypertension

- Essential Hypertension
 - no known cause
 - over 90% of all known cases
 - idiopathic Hypertension
- Secondary Hypertension
 - high blood pressure brought about by some other pathological condition such as renal or endocrine disease

Etiology of Essential Hypertension

- Genetic component
- Lack of exercise
- Obesity
- Poor nutritional status
- High alcohol consumption
- High sodium intake
- Stress

Treatment of Hypertension

- Weight Control
- Exercise
- Sodium Restriction in Diet
- Modify Drinking Habits
- Dietary Modifications
- Stress Management
- Drug Therapy

Hypertension

Occurs when a genetically susceptible individual is subjected to environmental factors such as high sodium intake, stress, poor nutritional and alcohol consumption habits, and lack of exercise, the conditions are established for the development of hypertension.

Myocardial Infarction (M.I.)

- Heart attack
- Heart muscle cell death
- A condition caused by partial or complete occlusion of one or more of the coronary arteries