Cardiac Anatomy

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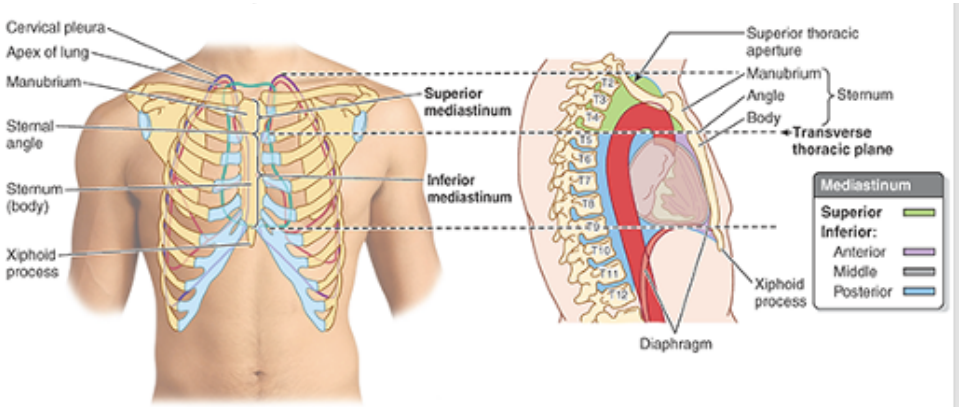
Overview of Mediastinum

- Occupied by the mass of tissue between the two pulmonary cavities, is the central compartment of the thoracic cavity.
- Is covered on each side by mediastinal pleura and contains all the thoracic viscera and structures except the lungs.

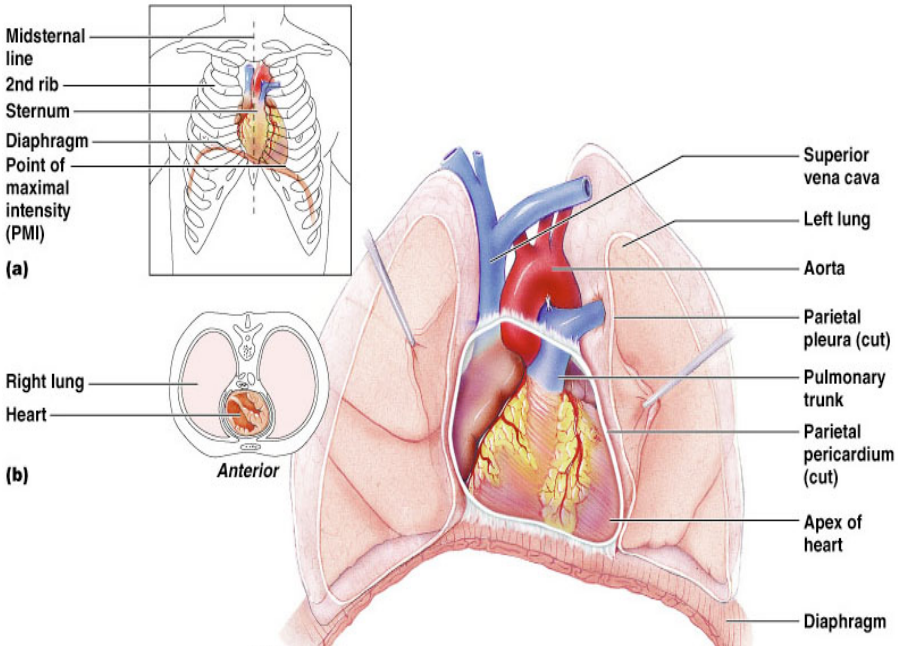
Mediastinum Borders

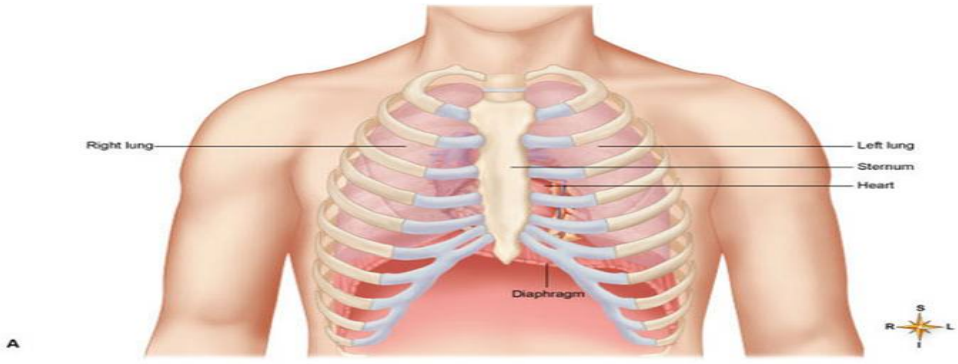
- The mediastinum extends from the superior thoracic aperture to the diaphragm inferiorly and from the sternum and costal cartilages anteriorly to the bodies of the thoracic vertebrae posteriorly.
- The mediastinum in living people is a highly mobile region because it consists primarily of hollow (liquid- or air-filled) visceral structures united only by loose connective tissue, often infiltrated with fat.

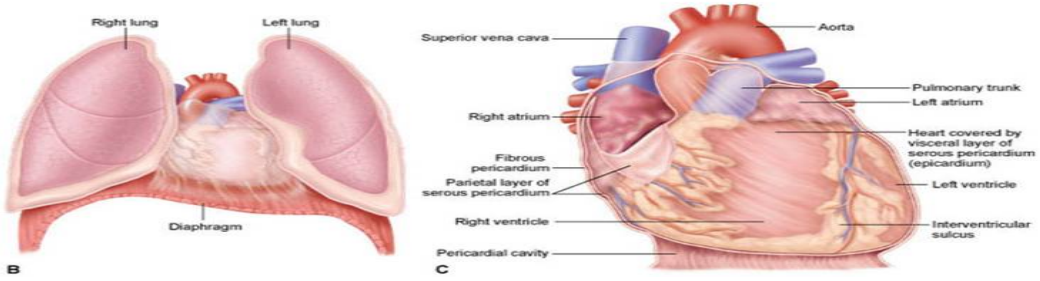


Location of Heart

- Approximately the size of your fist, approximately 12 ounces
- Location
    - Superior surface of diaphragm
    - Left of the midline in mediastinum
    - Anterior to the vertebral column, posterior to the sternum
    - Posteriorly the heart rests on the bodies of vertebrae T5-T8
    - Apex lies on the diaphragm, pointing to the left
    - Base lies just below the second rib
- PMI – point of maximal intensity is the place where you feel and hear the heart the best
    - It is located between the 5th and 6th rib on the left.





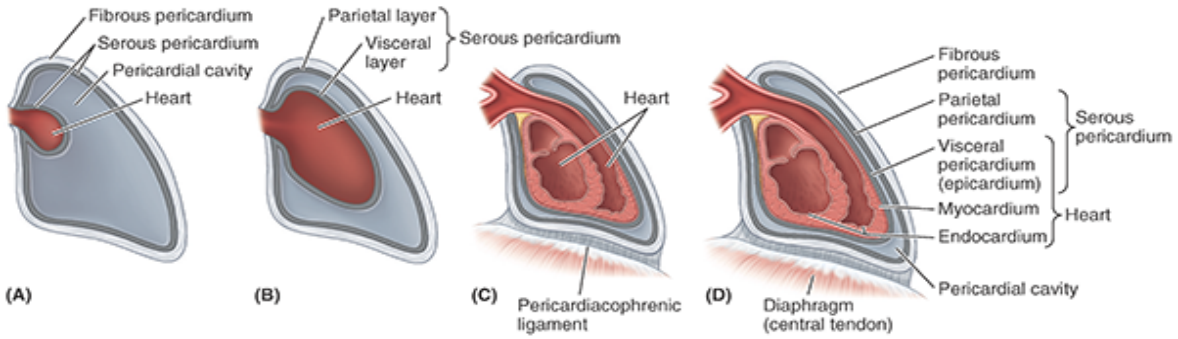


Four "Corners" of the Heart

- **Superior right -** At costal cartilage of third rib and sternum
- **Inferior right -** At costal cartilage of sixth rib lateral to the sternum
- **Superior left -** At costal cartilage of second rib lateral to the sternum
- **Inferior left -** Lies in the fifth intercostal space at the midclavicular line

Structure of the Heart - Coverings of the Heart

- Pericardium – has two primary layers
- A superficial fibrous pericardium
    - A strong layer of dense connective tissue
- A deep two-layer serous pericardium
    - The parietal layer lines the internal surface of the fibrous pericardium
    - The visceral layer or epicardium lines the surface of the heart
        - This visceral layer is the epicardium
    - They are separated by the fluid-filled pericardial cavity



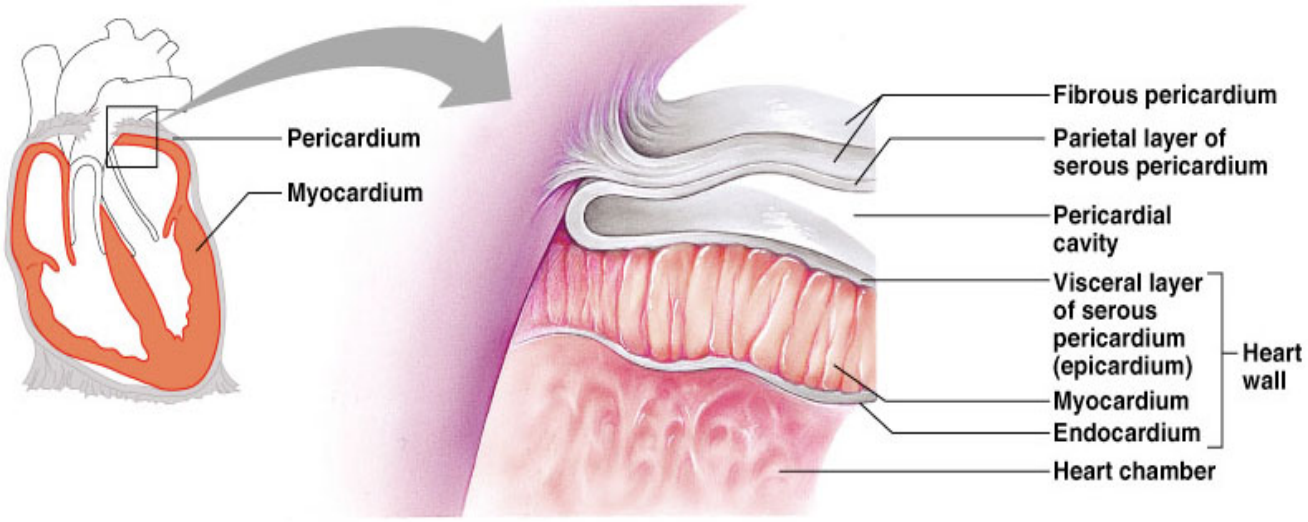
Diagrammatic right lateral views

Pericardium

- The nerve supply of the pericardium is from the phrenic nerves (C3–C5), primary source of sensory fibers
- Pain sensations conveyed by these nerves are commonly referred to the skin (C3–C5 dermatomes)
- Vagus nerves
- Sympathetic trunks, vasomotor

Structure of the Heart - Coverings of the Heart

- Functions of the pericardium
    - Protects and anchors the heart
    - Prevents overfilling of the heart with blood
    - Allows for the heart to work in a relatively friction-free environment
- Pericarditis – Inflammation of the Pericardium
    - The serous membrane is roughened up
    - When the heart beats, it rubs against the pericardial sac, creating a “grating” sound
    - Characterized by deep pain
    - In severe cases a large amount of inflammatory fluid seeps into the pericardial cavity causing a compression when the heart beats
        - Cardiac Tamponade

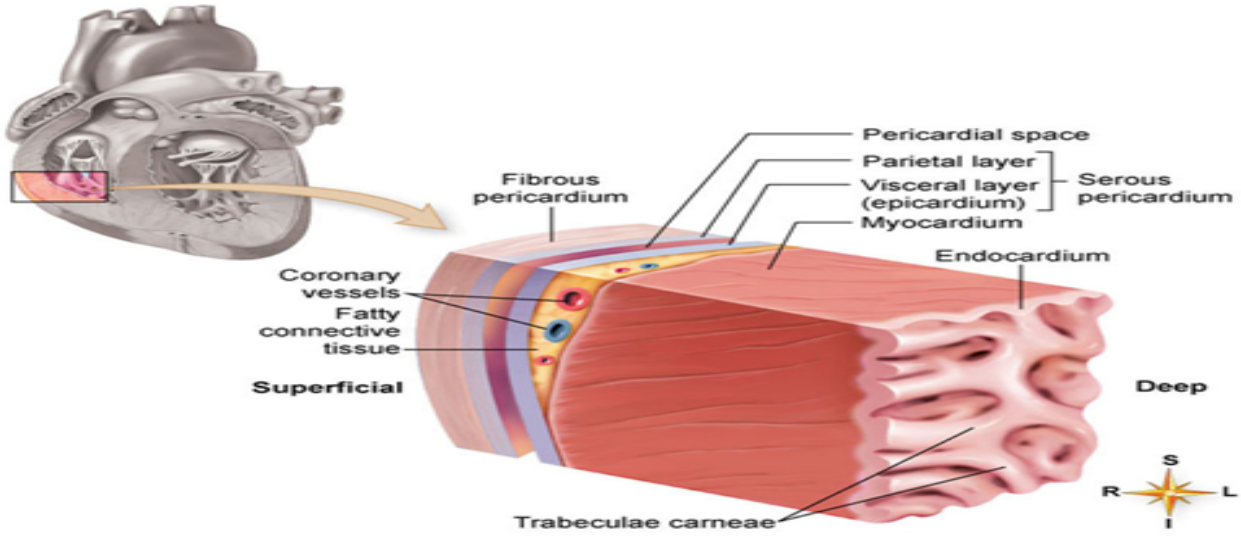


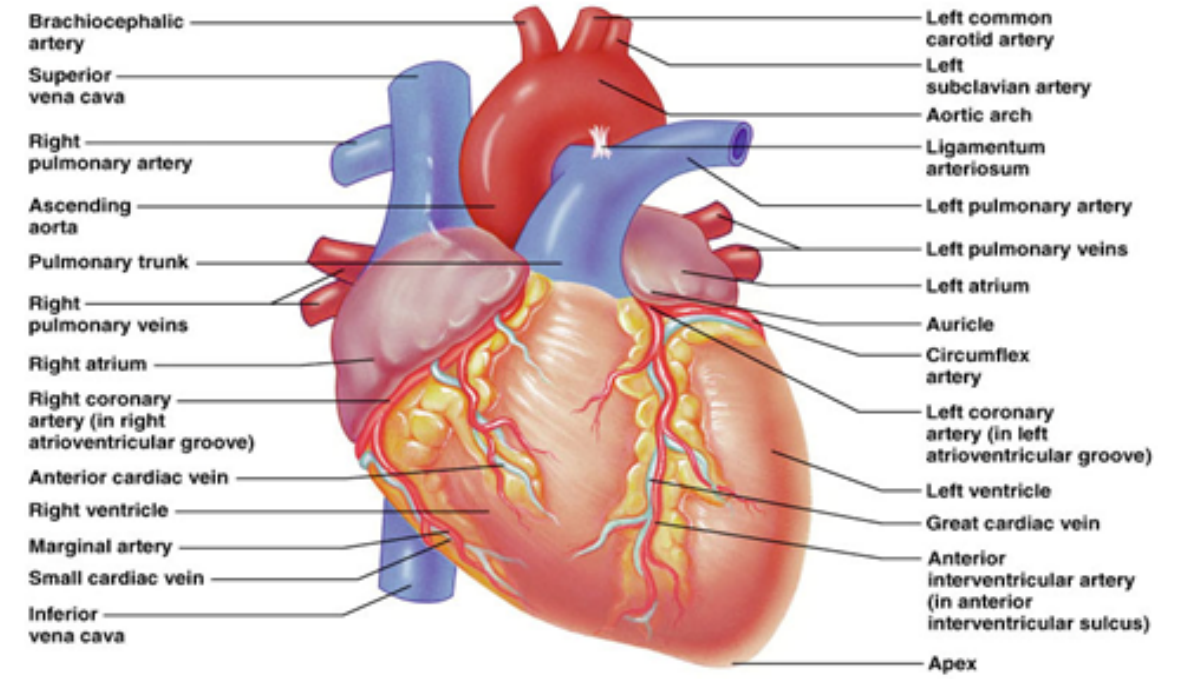
Structure of the Heart - Coverings of the Heart

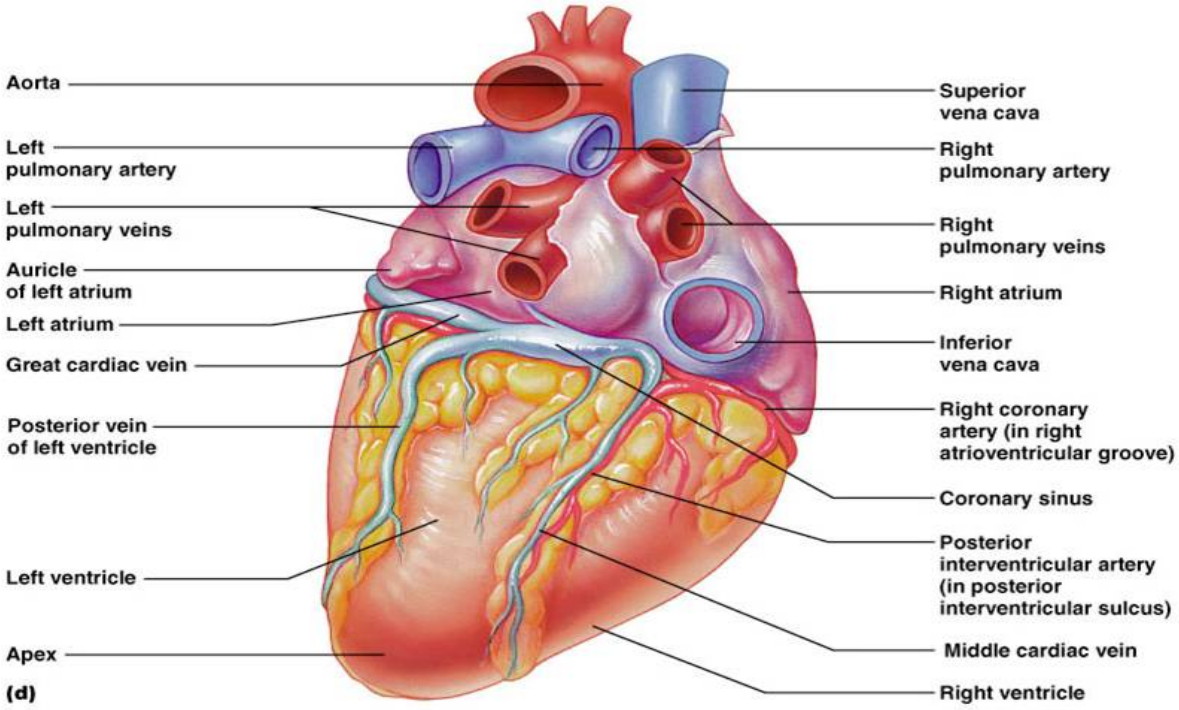
- Myocardium
  - Consists of cardiac muscle
    - Three times thicker on the left
  - Muscle arranged in circular and spiral patterns
- Endocardium
  - Endothelium resting on a layer of connective tissue
  - Lines the internal walls of the heart

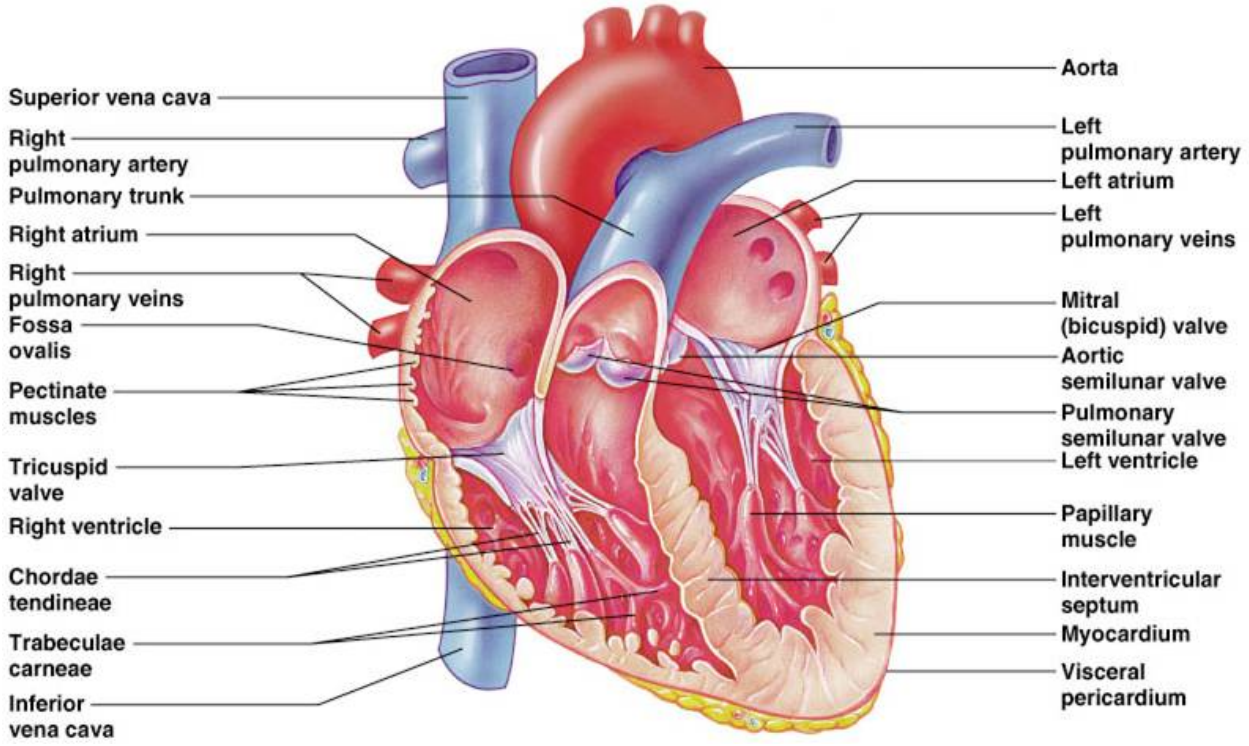
Wall of the Heart

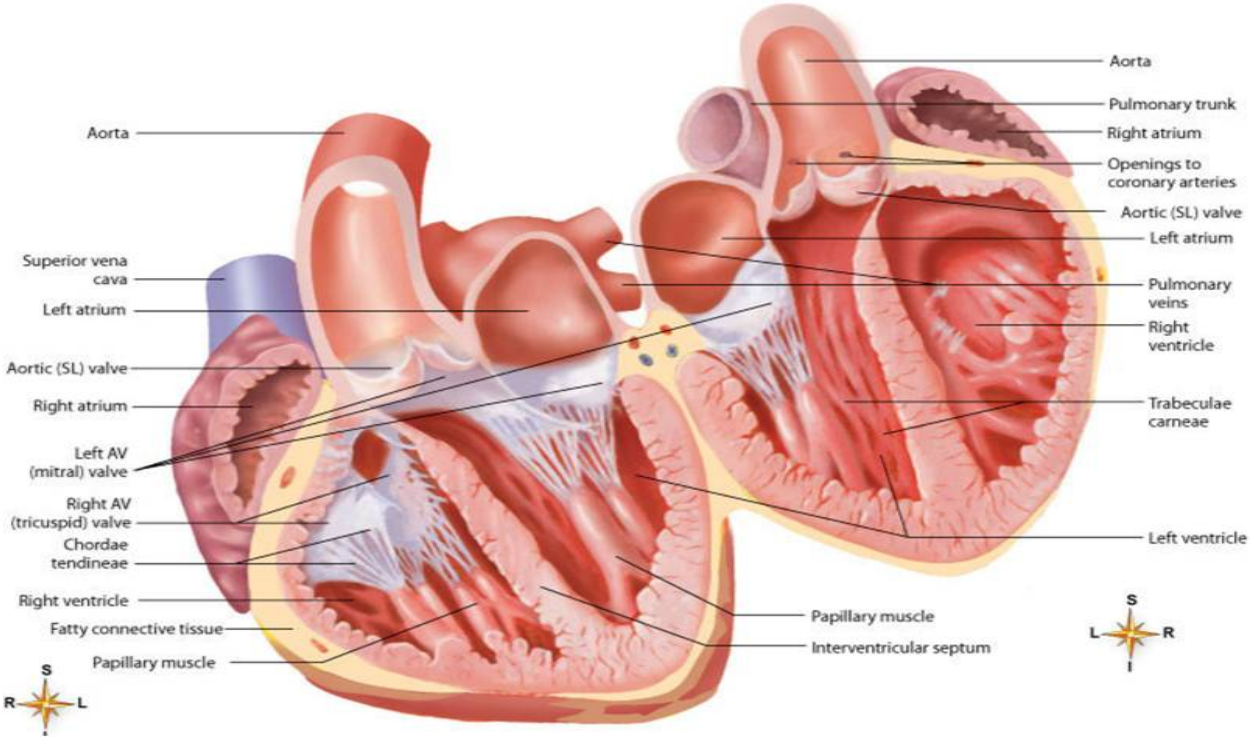
- Structure of the heart
- Wall of the heart: composed of three distinct layers
  - Epicardium: outer layer of heart wall
  - Myocardium: thick, contractile middle layer of heart wall; compresses the heart cavities, and the blood within them, with great force
  - Endocardium: delicate inner layer of endothelial tissue




Brachiocephalic artery
Superior vena cava
Right pulmonary artery
Ascending aorta
Pulmonary trunk
Right pulmonary veins
Right atrium
Right coronary artery (in right atrioventricular groove)
Anterior cardiac vein
Right ventricle
Marginal artery
Small cardiac vein
Inferior vena cava
Left common carotid artery
Left subclavian artery
Aortic arch
Ligamentum arteriosum
Left pulmonary artery
Left pulmonary veins
Left atrium
Auricle
Circumflex artery
Left coronary artery (in left atrioventricular groove)
Left ventricle
Great cardiac vein
Anterior interventricular artery (in anterior interventricular sulcus)
Apex


Aorta
Left pulmonary artery
Left pulmonary veins
Auricle of left atrium
Left atrium
Great cardiac vein
Posterior vein of left ventricle
Left ventricle
Apex
(d)
Superior vena cava
Right pulmonary artery
Right pulmonary veins
Right atrium
Inferior vena cava
Right coronary artery (in right atrioventricular groove)
Coronary sinus
Posterior interventricular artery (in posterior interventricular sulcus)
Middle cardiac vein
Right ventricle


Superior vena cava
Right pulmonary artery
Pulmonary trunk
Right atrium
Right pulmonary veins
Fossa ovalis
Pectinate muscles
Tricuspid valve
Right ventricle
Chordae tendineae
Trabeculae carneae
Inferior vena cava
Aorta
Left pulmonary artery
Left atrium
Left pulmonary veins
Mitral (bicuspid) valve
Aortic semilunar valve
Pulmonary semilunar valve
Left ventricle
Papillary muscle
Interventricular septum
Myocardium
Visceral pericardium


Aorta
Superior vena cava
Left atrium
Aortic (SL) valve
Right atrium
Left AV (mitral) valve
Right AV (tricuspid) valve
Chordae tendineae
Right ventricle
Fatty connective tissue
Papillary muscle
S
R
L
I
Aorta
Pulmonary trunk
Right atrium
Openings to coronary arteries
Aortic (SL) valve
Left atrium
Pulmonary veins
Right ventricle
Trabeculae carneae
Left ventricle
Papillary muscle
Interventricular septum
S
L
R
I

Heart Chambers

- Heart is divided into four cavities with the right and left chambers separated by the septum
    - Interventricular septa
    - Interatrial septa
- Atria of the Heart - Receiving Vessels
    - Superior chambers
    - Are the receiving chambers of the heart
    - Atria alternately contract and relax to receive blood and then push it into ventricles
    - Only a minimal contraction is needed to push the blood “downstairs” to the ventricles.
    - Each atrium has a protruding auricle
    - Blood enters right atria from superior and inferior venae cavae and coronary sinus
    - Blood enters left atria from pulmonary veins
- Ventricles of the Heart - Discharging Chambers
    - Inferior chambers
    - Ventricles are the discharging chambers of the heart – The actual heart pumps
    - The ventricles make up most of the volume of the heart
    - Right ventricle pumps blood into the pulmonary trunk
    - Left ventricle pumps blood into the aorta
- External markings
    - Coronary sulcus
    - Anterior interventricular sulcus
    - Posterior interventricular sulcus

Right Atrium

- Forms right border of heart
- Receives oxygen-poor blood from systemic circuit through these vessels:
    - Superior vena cava
    - Inferior vena cava
    - Coronary sinus
- Pectinate muscles
    - Ridges inside anterior of right atrium
    - Ridges inside anterior of right atrium
    - Has muscle fibers arranged in a comb like fashion. (Comb = Pectin *L*)
    - Can stretch and improve the voluminous nature of right atrium
    - Pectinate muscles are useful in increasing the power of contraction without increasing heart mass substantially.

Right Atrium

- Crista terminalis
    - Landmark used to locate veins entering right atrium
- Fossa ovalis
    - Depression in interatrial septum which is a remnant of foramen ovale

Right Ventricle

- Receives blood from right atrium through the right atrioventricular valve (tricuspid valve)
- Pumps blood into pulmonary circuit the pulmonary trunk
- Internal walls of right ventricle
    - Trabeculae carneae
    - Papillary muscles
    - Chordae tendineae
- Pulmonary semilunar valve (pulmonary valve)
    - Located at opening of right ventricle and pulmonary trunk

Left Atrium

- Makes up heart's posterior surface
- Receives oxygen-rich blood from lungs through pulmonary veins
- Opens into the left ventricle through
    - Left atrioventricular valve (bicuspid valve) also called mitral valve

Left Ventricle

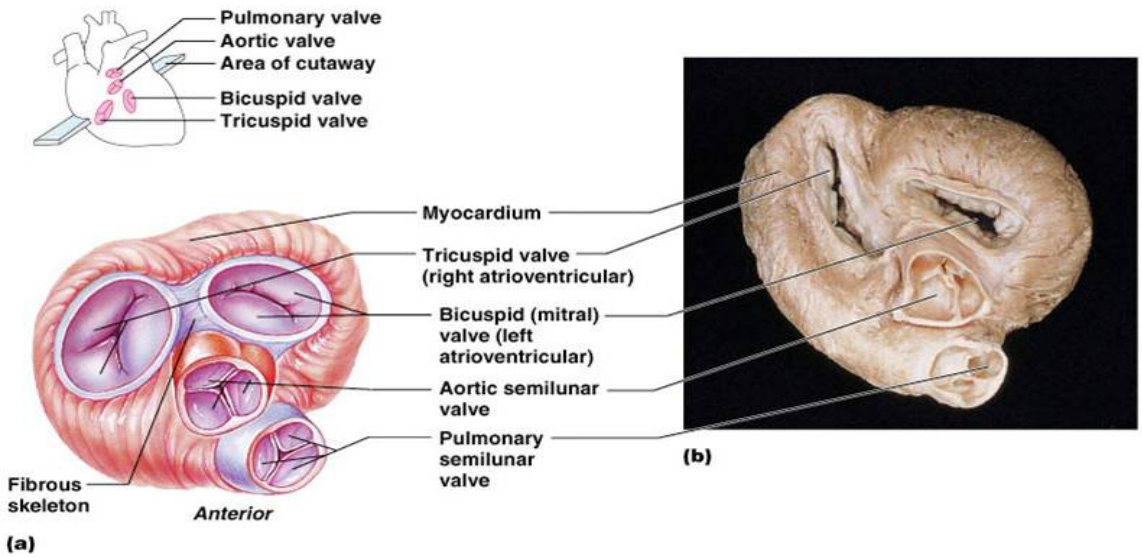
- Forms apex of the heart
- Internal walls of left ventricle
    - Trabeculae carneae
        - Assist in pulling with the papillary muscles
        - Prevents to wall from flattening
    - Papillary muscles - Connects to the myocardium to contract
    - Chordae tendineae - Connects to the valves - "heart strings"
- Pumps blood through systemic circuit via
    - Aortic semilunar valve (aortic valve)

Heart Valves

- Heart valves ensure unidirectional blood flow through the heart
- Atrioventricular (AV) valves lie between the atria and the ventricles
    - Tricuspid and bicuspid
- Semilunar valve lies between the ventricles and the great vessels
    - Aortic and pulmonary

Atrioventricular (AV) Valves

- All valves are composed of endocardium with a connective tissue core
- Atrioventricular (AV) valves: prevent blood from flowing back into the atria from the ventricles when the ventricles contract
    - Tricuspid valve (right AV valve): guards the right atrioventricular orifice; free edges of three flaps of endocardium are attached to papillary muscles by chordae tendineae
    - Bicuspid, or mitral, valve (left AV valve): similar in structure to tricuspid valve except has only two flaps

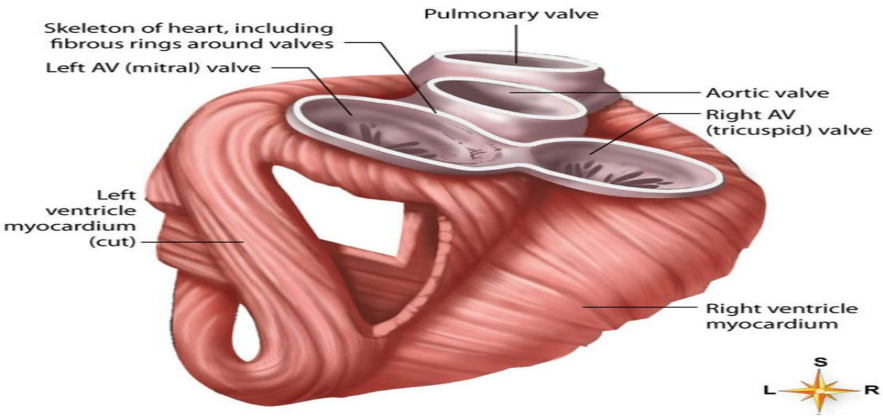


Semilunar (SL) Valves

- Semilunar valves: half-moon–shaped flaps growing out from the lining of the pulmonary artery and aorta; prevent blood from flowing back into the ventricles from the aorta and pulmonary artery
    - Pulmonary valve: valve at entrance of the pulmonary artery
    - Aortic valve: valve at entrance of the aorta

Cardiac Skeleton

- Surrounds all four valves
    - Composed of dense connective tissue
- Set of connected rings that serve as a semirigid support for the heart valves and the attachment of cardiac muscle of the myocardium
- Serves as an electrical barrier between the myocardium of the atria and that of the ventricles
- Functions of cardiac skeleton
    - Anchors valve cusps
    - Prevents overdilation of valve openings
    - Main point of insertion for cardiac muscle
    - Blocks direct spread of electrical impulses



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 (start of the heart contraction)
    - Second sound occurs when SL valves close at the beginning of ventricular diastole (relaxation of the heart muscle)
    - Clinically significant because they provide information about the functioning of the heart valves

Heart Murmurs

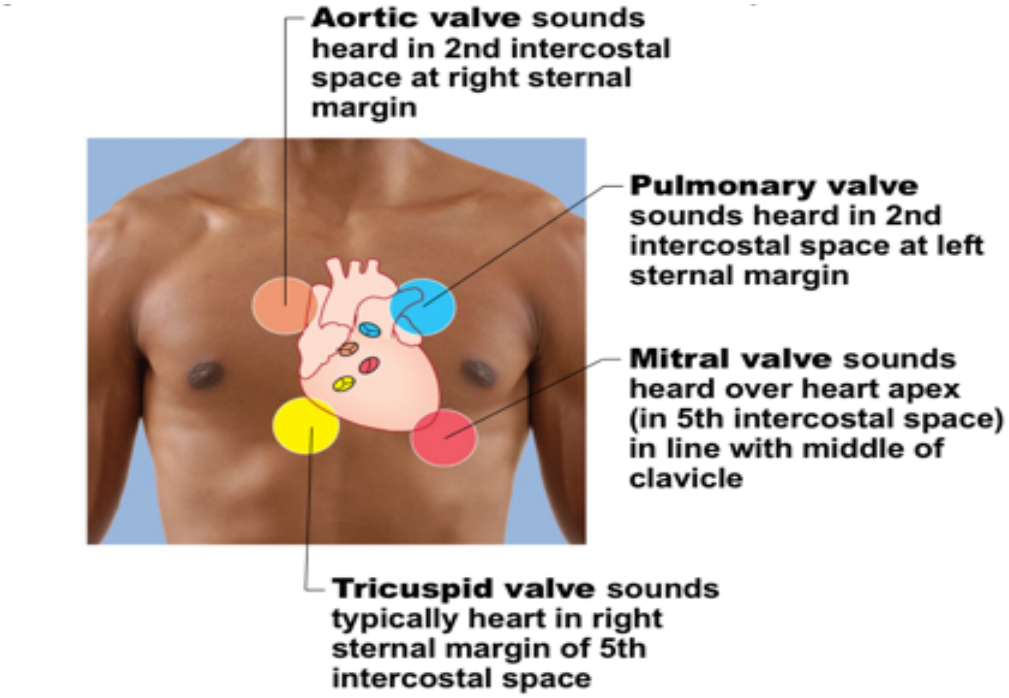
- Abnormal heart sounds are called murmurs
- Blood flows silently as long as the flow is smooth and interrupted
- If there is an obstruction, the flow becomes turbulent and generates a detectable sound
- Common in young children and some elderly
    - Probably because the heart walls are thinner and vibrate more

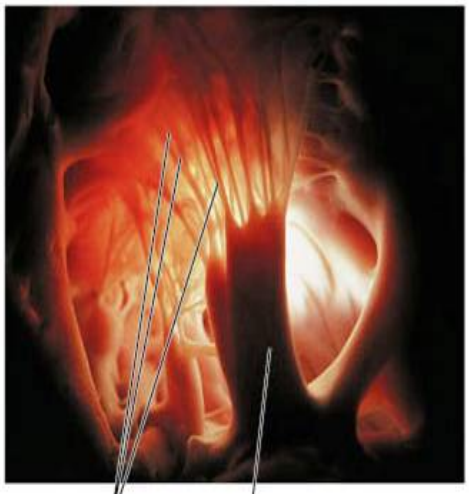
Pathway of Blood Through the Heart

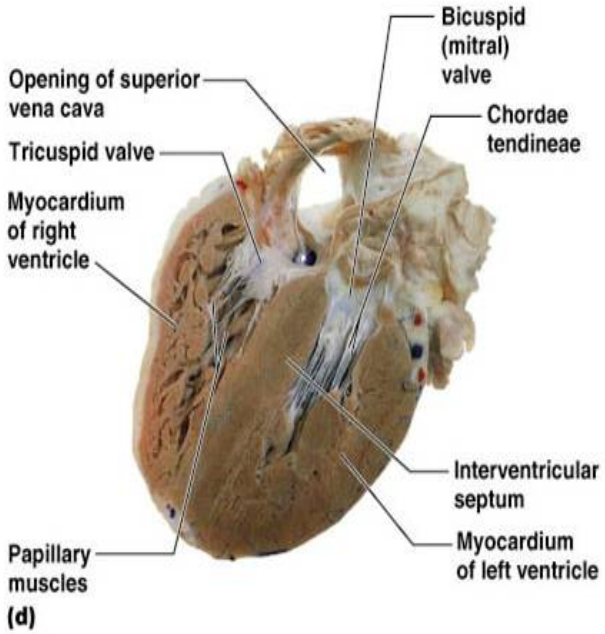
- Beginning with oxygen-poor blood in the superior and inferior venae cavae
    - Describe the pathway through
        - Pulmonary and systemic circuits
    - A blood drop passes through all structures sequentially
        - Atria contract together
        - Ventricles contract together

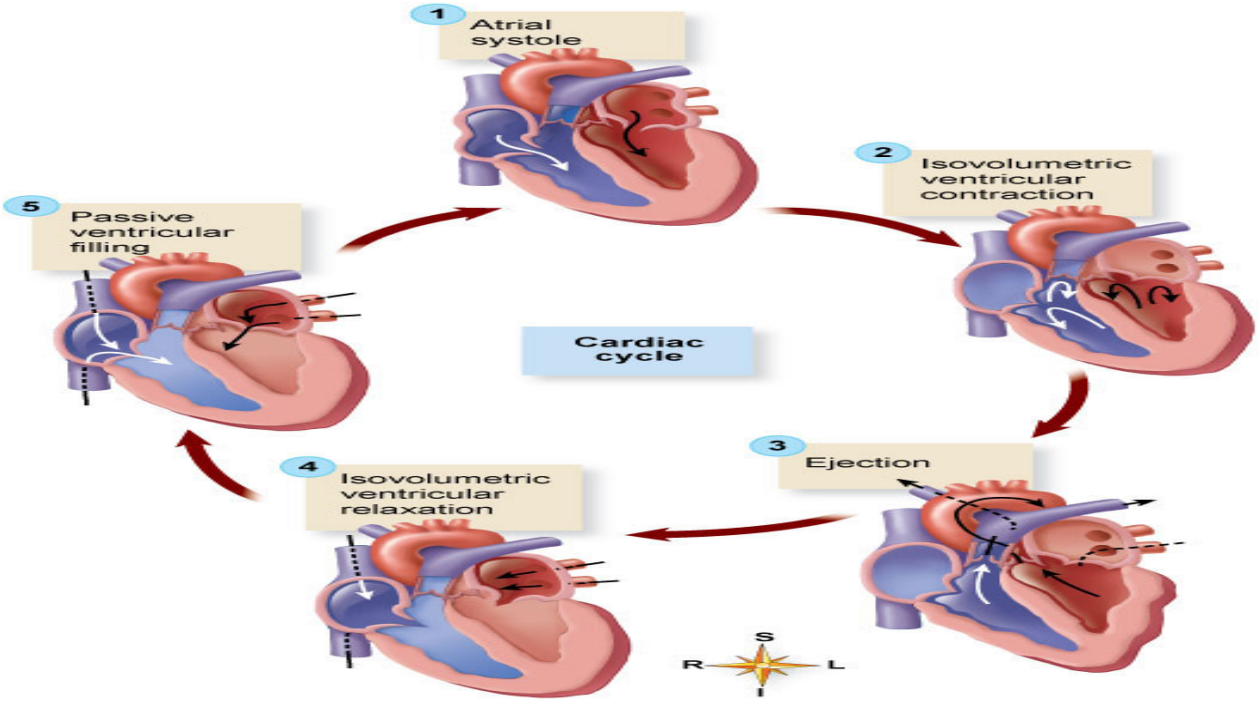
Heartbeat

- 70–80 beats per minute at rest
    - Systole—contraction of a heart chamber
    - Diastole—expansion of a heart chamber
- Systole and diastole also refer to
    - Stage of heartbeat when ventricles contract and expand


Aortic valve sounds heard in 2nd intercostal space at right sternal margin
Pulmonary valve sounds heard in 2nd intercostal space at left sternal margin
Mitral valve sounds heard over heart apex (in 5th intercostal space) in line with middle of clavicle
Tricuspid valve sounds typically heart in right sternal margin of 5th intercostal space


Chordae tendineae attached to tricuspid valve flap
Papillary muscle
(c)


Opening of superior vena cava
Tricuspid valve
Myocardium of right ventricle
Bicuspid (mitral) valve
Chordae tendineae
Interventricular septum
Myocardium of left ventricle
Papillary muscles
(d)



CO = HR X SV

- Cardiac Output is the amount of blood flowing through the heart in one minute
- Heart Rate is the beats per minute
- Stroke Volume is the strength of the contraction

Structure of Heart Wall

- Walls differ in thickness
  - Atria—thin walls
  - Ventricles—thick walls
- Systemic circulation
  - Longer than pulmonary circulation
  - Offers greater resistance to blood flow
- Left ventricle
  - Three times thicker than right ventricle
    - Exerts more pumping force
  - Flattens right ventricle into a crescent shape

Cardiac Muscle Tissue

- Cardiac muscle tissue forms the **myocardium**
  - Striated, like skeletal muscle
  - Contractions pump blood through the heart and into blood vessels
  - Contracts by sliding filament mechanism
- Cardiac muscle cells
  - Short, Branching
  - Have one or two nuclei

Cardiac Muscle Tissue - continued

- Cells join at intercalated discs
    - Complex junctions
    - Form cellular networks
- Cells are separated by delicate endomysium
    - Binds adjacent cardiac fibers
    - Contains blood vessels and nerves
- Triggered to contract by Ca^{2+} entering the sarcoplasm
    - Signals sarcoplasmic reticulum to release Ca^{2+} ions
    - Ions diffuse into sarcomeres
        - Trigger sliding filament mechanism
- Not all cardiac cells are innervated
    - Will contract in rhythmic manner without innervation
    - Inherent rhythmicity
    - Is the basis for rhythmic heartbeat

Conducting System

- Cardiac muscle tissue has intrinsic ability to
- Generate and conduct impulses
- Signal these cells to contract rhythmically
- Conducting system is a series of specialized cardiac muscle cells
- Sinoatrial (SA) node sets the inherent rate of contraction

Nerve Supply of the Heart

- Conduction system of the heart: composed of modified cardiac muscle, it generates and distributes the heart's own rhythmic contractions; can be regulated by afferent nerves
- Most fibers end in the SA node, but some end in the AV node and in the atrial myocardium; the nodes are the heart's pacemakers
- Sympathetic nerves: accelerator nerves
- Vagus fibers: inhibitory, or depressor, nerves

Innervation

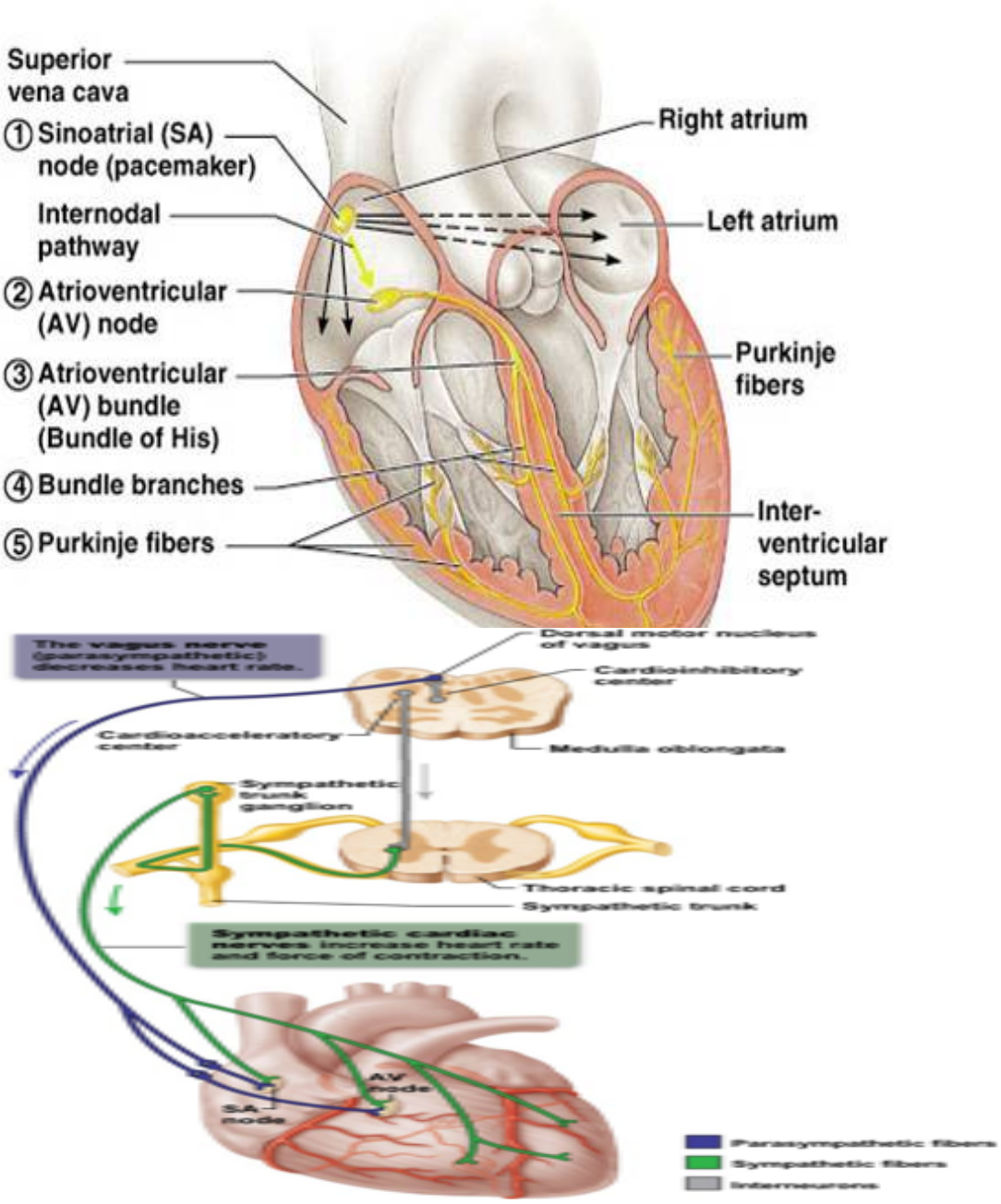
- Heart rate is set by SA node
- Rate is altered by extrinsic and neural controls
- Visceral sensory fibers
- Parasympathetic fibers
- Nerves pass through cardiac plexus
- **Parasympathetic fibers**
    - Branches of Vagus nerve
    - Decrease heart rate
    - Restricted to SA node, AV node, coronary arteries

Innervation - continued

- **Sympathetic nerves**
  - Travel to heart from cervical and upper thoracic chain ganglia
  - Innervate SA node, AV node, coronary arteries—as parasympathetic
  - Also innervate cardiac musculature throughout the heart
  - Increase heart rate and strength of contraction

Autonomic Input

- Controlled by cardiac centers in reticular formation of medulla
- Cardioinhibitory center - Influences parasympathetic neurons
- Cardioacceleratory center - Influences sympathetic neurons



Blood Supply to the Heart

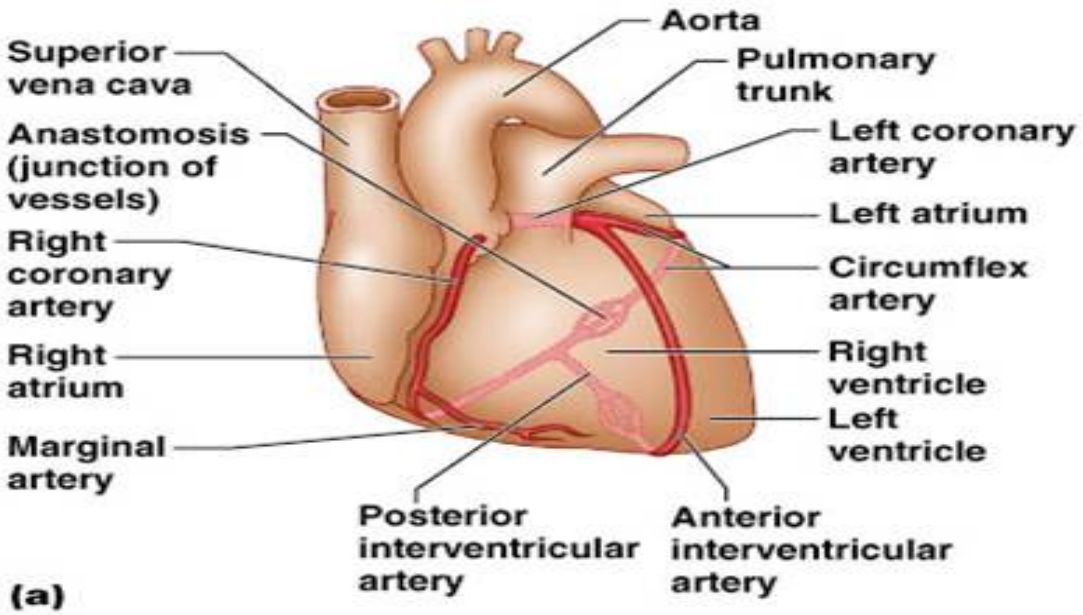
- **Coronary arteries**
  - Blood supply to the muscular walls and tissues of the heart
- **Left coronary artery (LCA)**
  - Arise from base of the aorta and run in the coronary sulcus
  - Branches into anterior interventricular artery and circumflex artery
  - Left anterior descending artery (LAD) is the clinical name for anterior interventricular artery
- **Right coronary artery (RCA)** descends in coronary sulcus
  - Branches to form the marginal artery
  - Later braches into the posterior interventricular artery
  - Clinically called posterior descending artery (PDA)

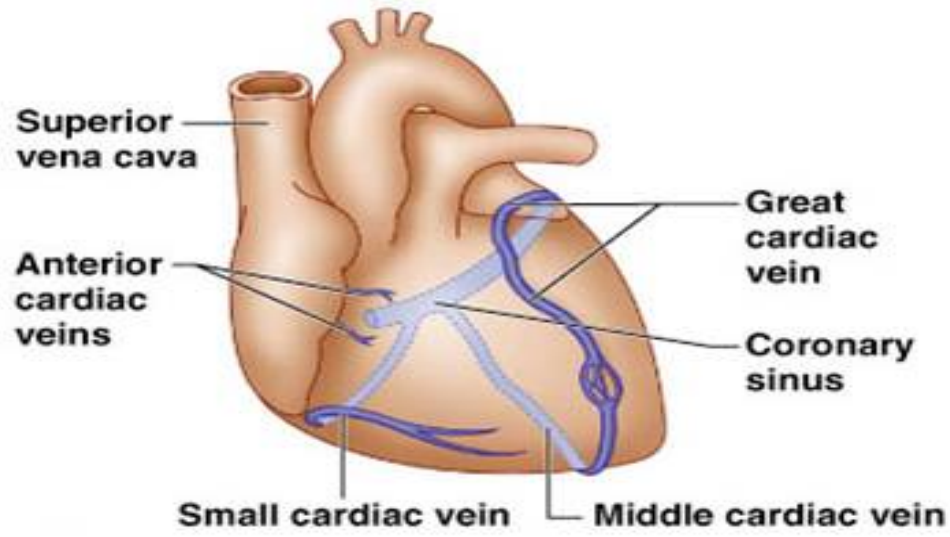
Cardiac Veins

- Carry deoxygenated blood from the heart wall to the right atrium
- Occupy sulci on the heart's surface
- Coronary sinus—runs in the posterior part of the coronary sulcus
- Returns majority of venous blood from the heart to the right atrium
- Three tributaries of coronary sinus
  - Great cardiac vein, middle cardiac vein, small cardiac vein

Coronary Circulation

- Coronary circulation is the functional blood supply to the heart muscle itself
- Collateral routes ensure blood delivery to heart even if major vessels are occluded
- Angina pectoris – thoracic pain caused by blood deficiency to the heart
- MI is caused by prolonged blockage
- Blockage of the coronary artery can be fatal





Disorders of the Heart

- Coronary artery disease
- Atherosclerosis—fatty deposits
- Angina pectoris—chest pain
- Myocardial infarction—blocked coronary artery
- Heart attack
- Silent ischemia—no pain or warning

Disorders of the Heart

- **Heart failure**
  - Progressive weakening of the heart
  - Cannot meet the body's demands for oxygenated blood
- **Congestive heart failure (CHF)**
  - Heart enlarges
  - Pumping efficiency declines
- **Pulmonary arterial hypertension**
  - Enlargement and potential failure of right ventricle

Disorders of the Conduction System

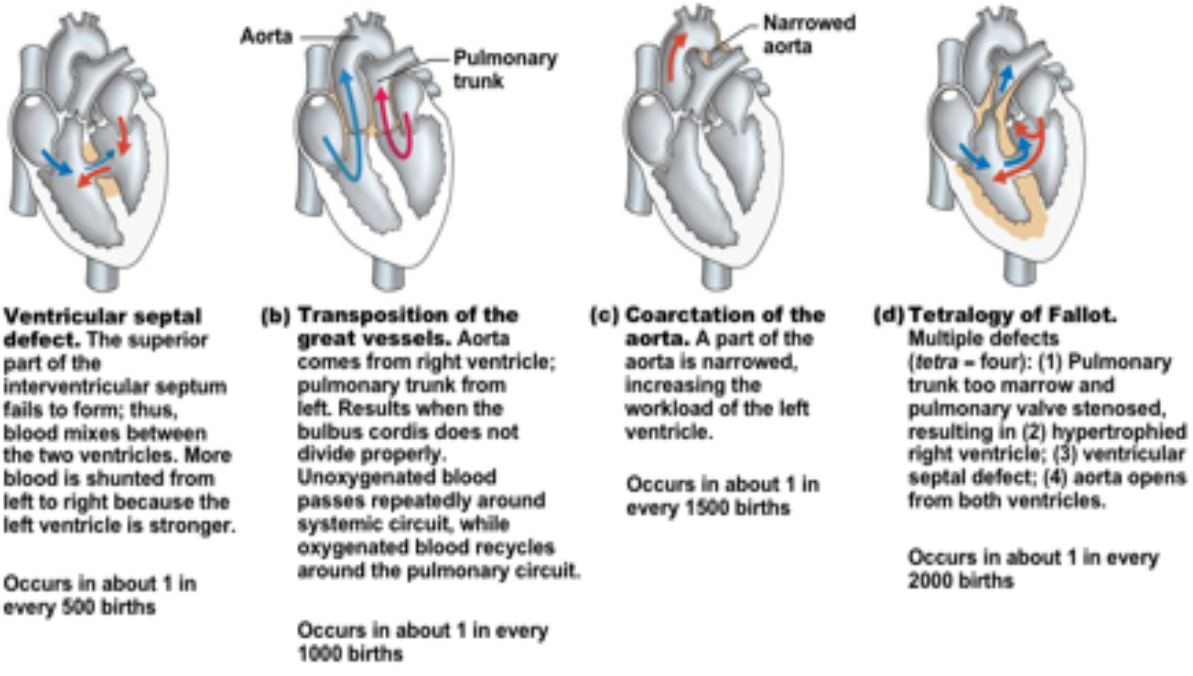
- **Arrythmias**—variation from normal heart rhythm
- **Ventricular fibrillation**
  - Rapid, random firing of electrical impulses in the ventricles
  - Results from crippled conducting system
  - Common cause of cardiac arrest
- **Atrial fibrillation**
  - Impulses circle within atrial myocardium, stimulating AV node
  - Promotes formation of clots
  - Leads to strokes
  - Occurs in episodes characterized by anxiety, fatigue, shortness of breath, palpitations

Development of the Heart

- Heart folds into thorax region about day 20–21
- Heart starts pumping about day 22
- Earliest heart chambers are unpaired
- Sinus venosus
    - Will become smooth-walled part of right atrium, coronary sinus, and SA node
    - Also contributes to back wall of left atrium
- Atrium
    - Will become ridged parts of right and left atria
- Ventricle
    - Is the strongest pumping chamber
    - Gives rise to the left ventricle
- Bulbus cordis
    - Bulbus cordis and truncus arteriosus give rise to the pulmonary trunk and first part of aorta
    - Bulbus cordis gives rise to the left ventricle

Congenital Heart Defects

- Can be traced to month 2 of development
- Most common defect is ventricular septal defect
- Two basic categories of defect
    - Inadequately oxygenated blood reaches body tissues
    - Ventricles labor under increased workload



(a) Ventricular septal defect. The superior part of the interventricular septum fails to form; thus, blood mixes between the two ventricles. More blood is shunted from left to right because the left ventricle is stronger.

Occurs in about 1 in every 500 births

(b) Transposition of the great vessels. Aorta comes from right ventricle; pulmonary trunk from left. Results when the bulbus cordis does not divide properly. Unoxygenated blood passes repeatedly around systemic circuit, while oxygenated blood recycles around the pulmonary circuit.

Occurs in about 1 in every 1000 births

(c) Coarctation of the aorta. A part of the aorta is narrowed, increasing the workload of the left ventricle.

Occurs in about 1 in every 1500 births

(d) Tetralogy of Fallot. Multiple defects (*tetra* = four): (1) Pulmonary trunk too marrow and pulmonary valve stenosed, resulting in (2) hypertrophied right ventricle; (3) ventricular septal defect; (4) aorta opens from both ventricles.

Occurs in about 1 in every 2000 births

Cycle of Life : Cardiovascular Anatomy

- Birth: change from placenta-dependent system
- Heart and blood vessels maintain basic structure and function from childhood through adulthood
- Exercise thickens myocardium and increases the supply of blood vessels in skeletal muscle tissue
- Adulthood through later adulthood: degenerative changes
- Atherosclerosis: blockage or weakening of critical arteries
- Heart valves and myocardial tissue degenerate, reducing pumping efficiency

The Heart in Old Age

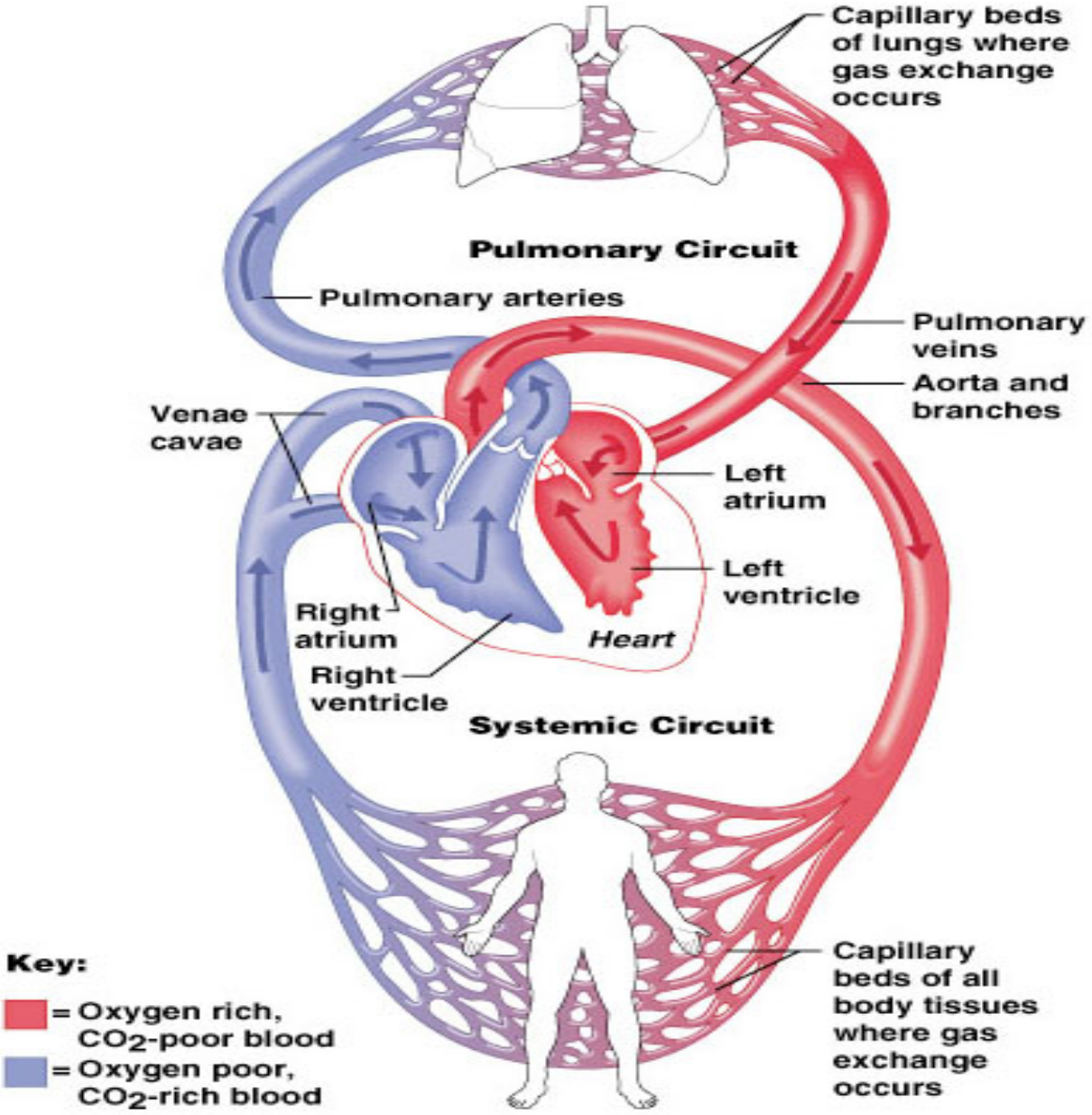
- Heart usually functions well throughout life
- Regular exercise increases the strength of the heart
- Aerobic exercise can help clear fatty deposits in coronary arteries
- Age-related changes
    - Hardening and thickening of heart valve cusps
    - Decline in cardiac reserve
    - Fibrosis of cardiac muscle

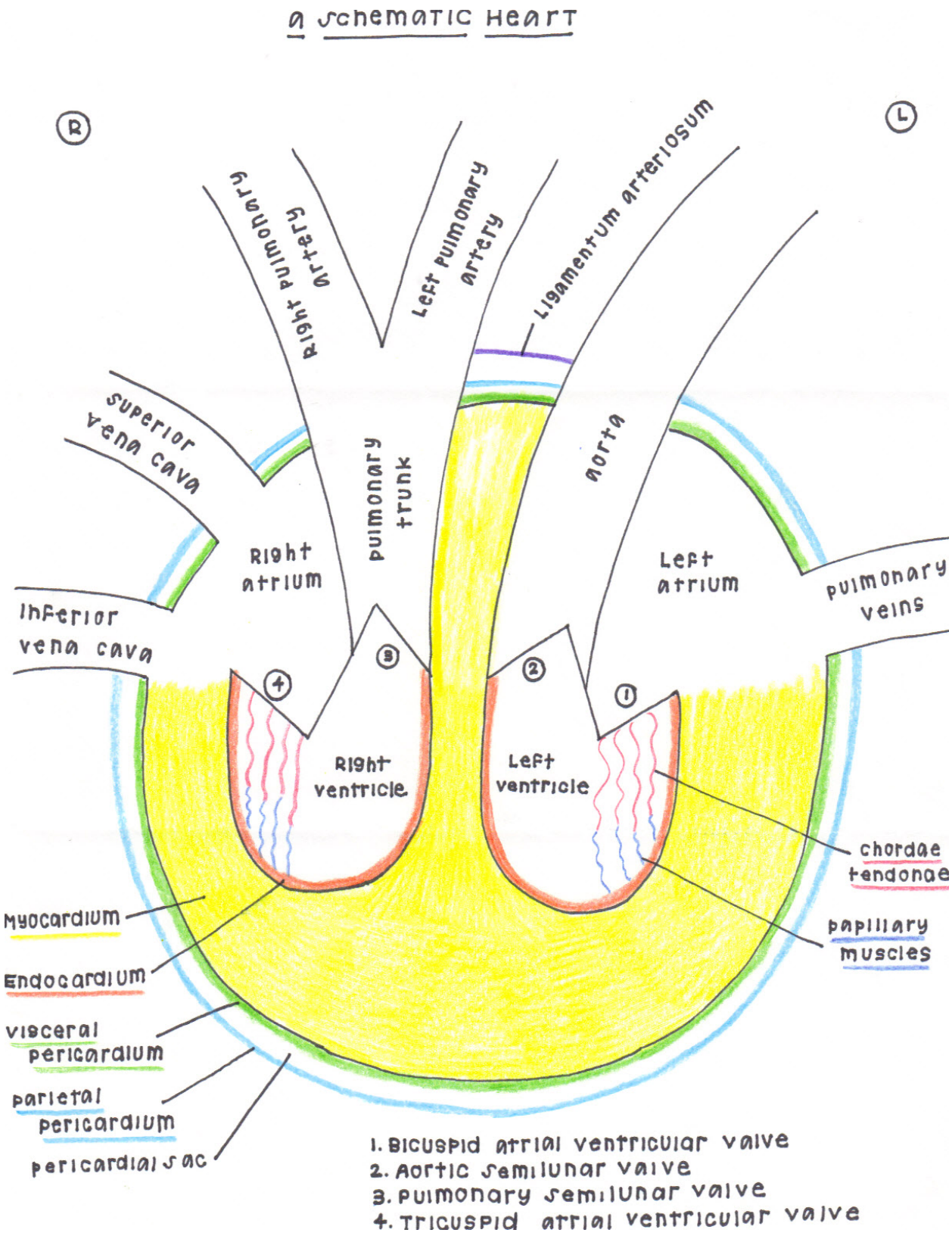
Circulatory Pathways

- The vascular system has two distinct circulations
    - Pulmonary circulation – short loop that runs from the heart to the lungs and back to the heart
    - Systemic circulation – routes blood through a long loop to all parts of the body and returns to the heart

Circulatory Routes

- Systemic circulation: blood flows from the left ventricle of the heart through blood vessels to all parts of the body (except gas exchange tissues of lungs) and back to the right atrium
- Pulmonary circulation: venous blood moves from right atrium to right ventricle to pulmonary artery to lung arterioles and capillaries, where gases are exchanged; oxygenated blood returns to left atrium by pulmonary veins; from left atrium, blood enters the left ventricle
- Systemic arteries
    - Main arteries give off branches, which continue to rebranch, forming arterioles and then capillaries
    - End arteries: arteries that eventually diverge into capillaries
    - Arterial anastomoses: arteries that open into other branches of the same or other arteries; incidence of arterial anastomoses increases as distance from the heart increases
    - Arteriovenous anastomoses, or shunts, occur when blood flows from an artery directly into a vein


Capillary beds of lungs where gas exchange occurs
Pulmonary Circuit
Pulmonary arteries
Pulmonary veins
Aorta and branches
Venae cavae
Left atrium
Left ventricle
Right atrium
Heart
Right ventricle
Systemic Circuit
Capillary beds of all body tissues where gas exchange occurs
Key:
= Oxygen rich, CO_2-poor blood
= Oxygen poor, CO_2-rich blood



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