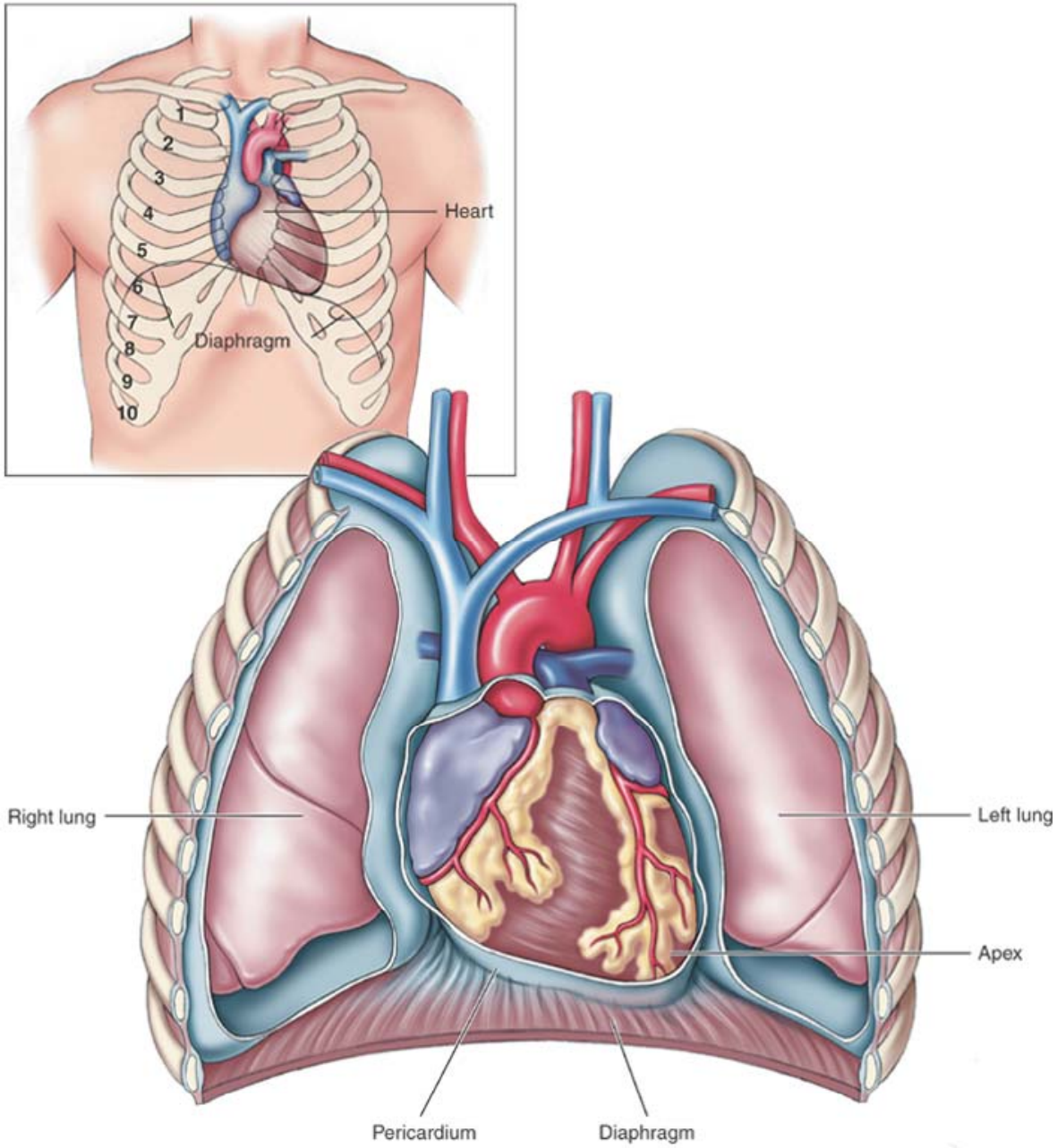
Heart

Rita Carey-Nita

Heart

- The heart is a hollow muscular organ about the size of a closed fist
- Sits inside the chest within the mediastinum, between the lungs
- Lies toward the left side of the body
- Flat upper portion is located at the level of the 2^{nd} rib
- The apex (lower portion) is located at the level of the 5^{th} & 6^{th} rib
- Lies within & is supported by the pericardium


1
2
3
4
5
6
7
8
9
10
Heart
Diaphragm
Right lung
Left lung
Apex
Pericardium
Diaphragm

Heart

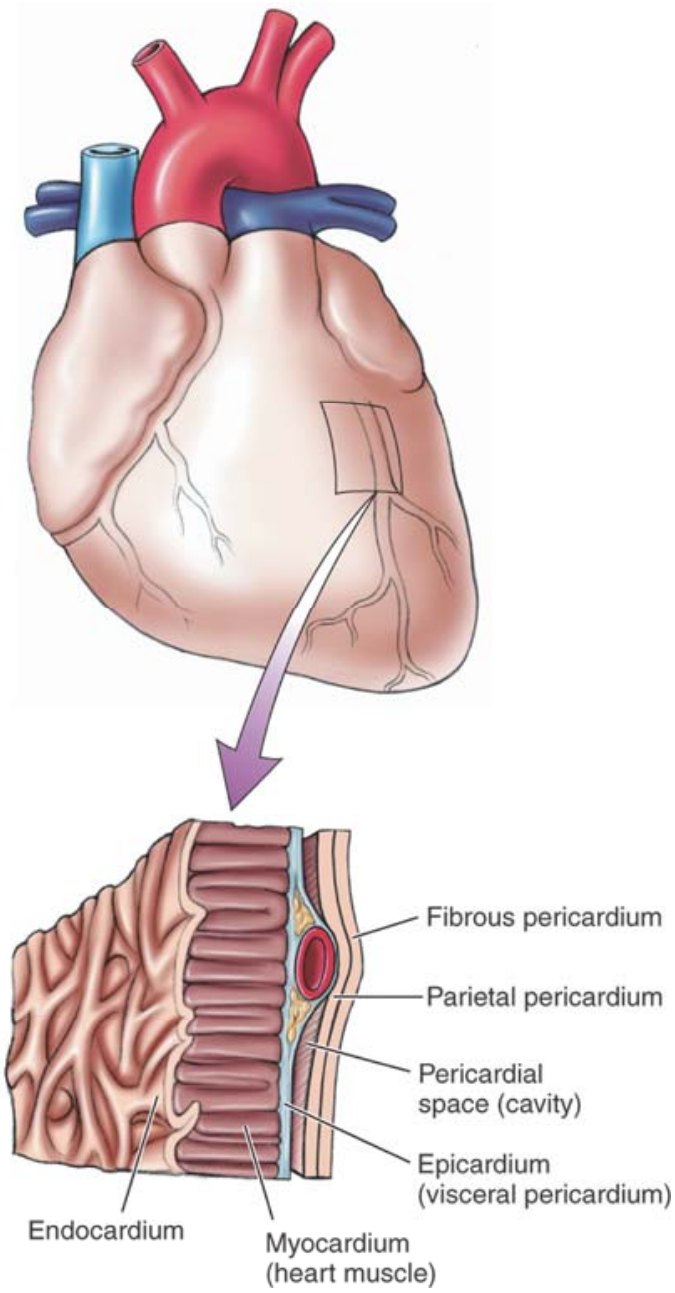
- Function of the heart is to pump blood through the blood vessels of the body, providing oxygen & nutrients to all cells
- The heart pumps on average 72 times/minute

Layers of the Heart

- Heart is made up of 3 layers:
  - Endocardium:
    - Innermost layer composed of thin layer of simple squamous epithelium over a layer of connective tissue
    - Smooth & shiny surface allows blood to flow easily
    - Lines valves & vessels entering & leaving heart

Layers of the Heart

- Myocardium:
  - Thick middle layer
  - Thickest of all layers composed of cardiac muscle tissue (actin, myosin & intercalated discs)
  - Allows the heart to contract, propelling blood through blood vessels
- Epicardium:
  - Thin outermost layer
  - Continuous at apex with the inner lining of the pericardium


Fibrous pericardium
Parietal pericardium
Pericardial space (cavity)
Epicardium (visceral pericardium)
Endocardium
Myocardium (heart muscle)

Heart

- Pericardium:
  - Sling like structure that supports the heart & attaches the heart to sternum & diaphragm
- Pericardial space:
  - serous membrane located between the epicardium & pericardium
  - serous membrane secretes serous fluid (pericardial fluid) that lubricates the surfaces of the membranes allowing them to slide past one another without rubbing or friction

Heart

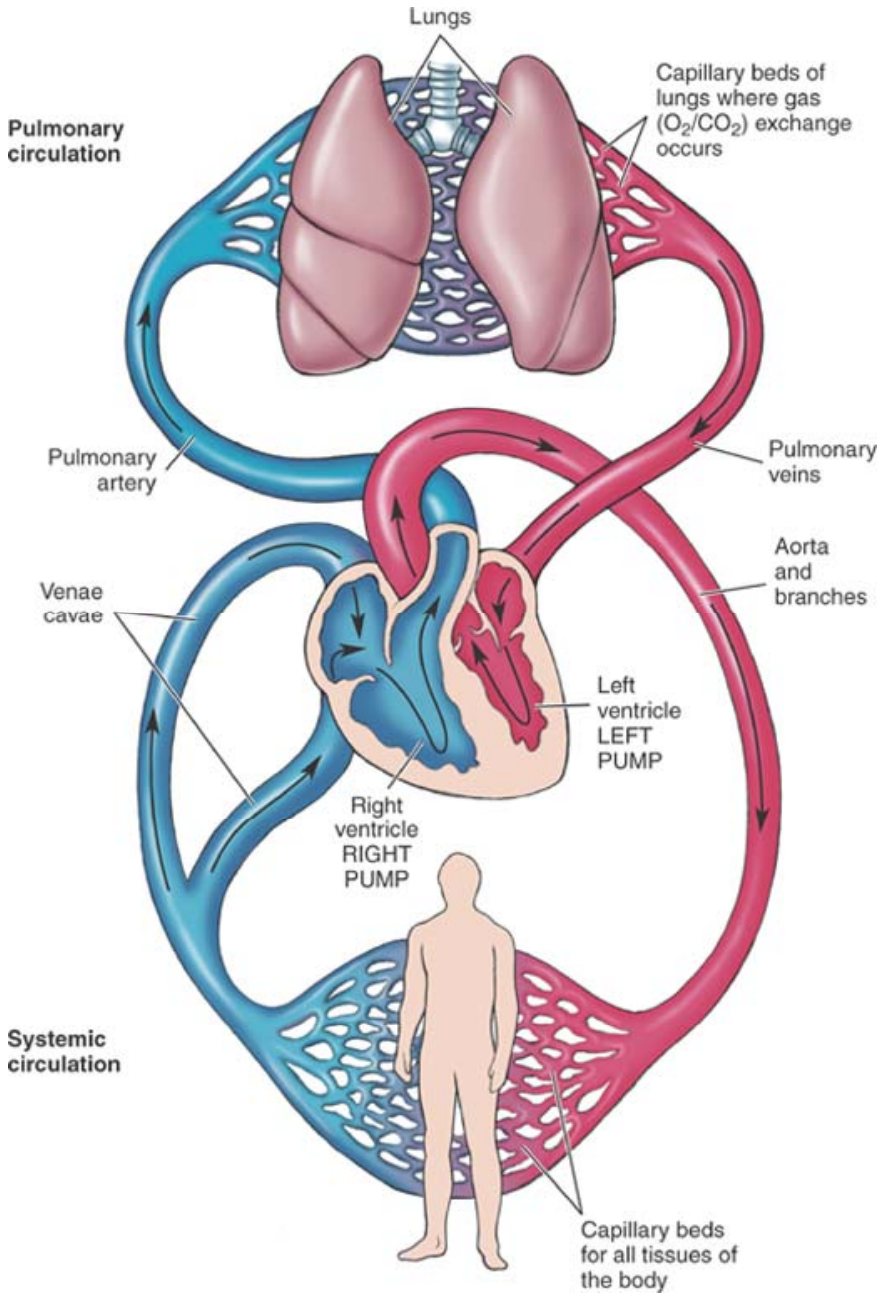
- Two pumps & two circulations:
- The pumps are the:
  - left side of the heart
  - right side of the heart
- The two circulations are:
  - pulmonary circulation
  - systemic circulation

Circulation

- The right side of the heart:
  - Receives deoxygenated blood from the superior & inferior vena cava
  - Pumps blood to the lungs where the blood is oxygenated
  - The blood travels from the right side of the heart to the lungs then back to the left side of the heart
  - This path is called pulmonary circulation
  - Only function of pulmonary circulation is to circulate the blood to the lungs for oxygen & to rid the body of carbon dioxide

Circulation

- The left side of the heart:
  - Receives the oxygenated blood from the lungs & pumps out the aorta to all the organs of the body
  - The path the blood take from the left side of the heart to the organs of the body & then back to the right side of the heart is called systemic circulation


Lungs
Capillary beds of lungs where gas (O_2/CO_2) exchange occurs
Pulmonary circulation
Pulmonary artery
Pulmonary veins
Aorta and branches
Venae cavae
Left ventricle LEFT PUMP
Right ventricle RIGHT PUMP
Systemic circulation
Capillary beds for all tissues of the body

Chambers of Heart

- Heart has 4 chambers:
  - 2 atria & 2 ventricles
- The atria:
  - Right & Left Upper chambers of heart
  - Receive blood
- The ventricles:
  - Right & Left Lower chambers of heart
  - Pump blood out of heart

Chambers of Heart

- Right & left heart are separated by septum
  - Interatrial septum separates atria
  - Interventricular septum separates ventricles

Chambers & Vessels

- Right atrium:
  - Is thin-walled cavity
  - Receives unoxygenated blood from large veins
  - Superior vena cava collects blood form the heart & upper body region
  - Inferior vena cava receives blood from the lower part of the body

Chambers & Vessels

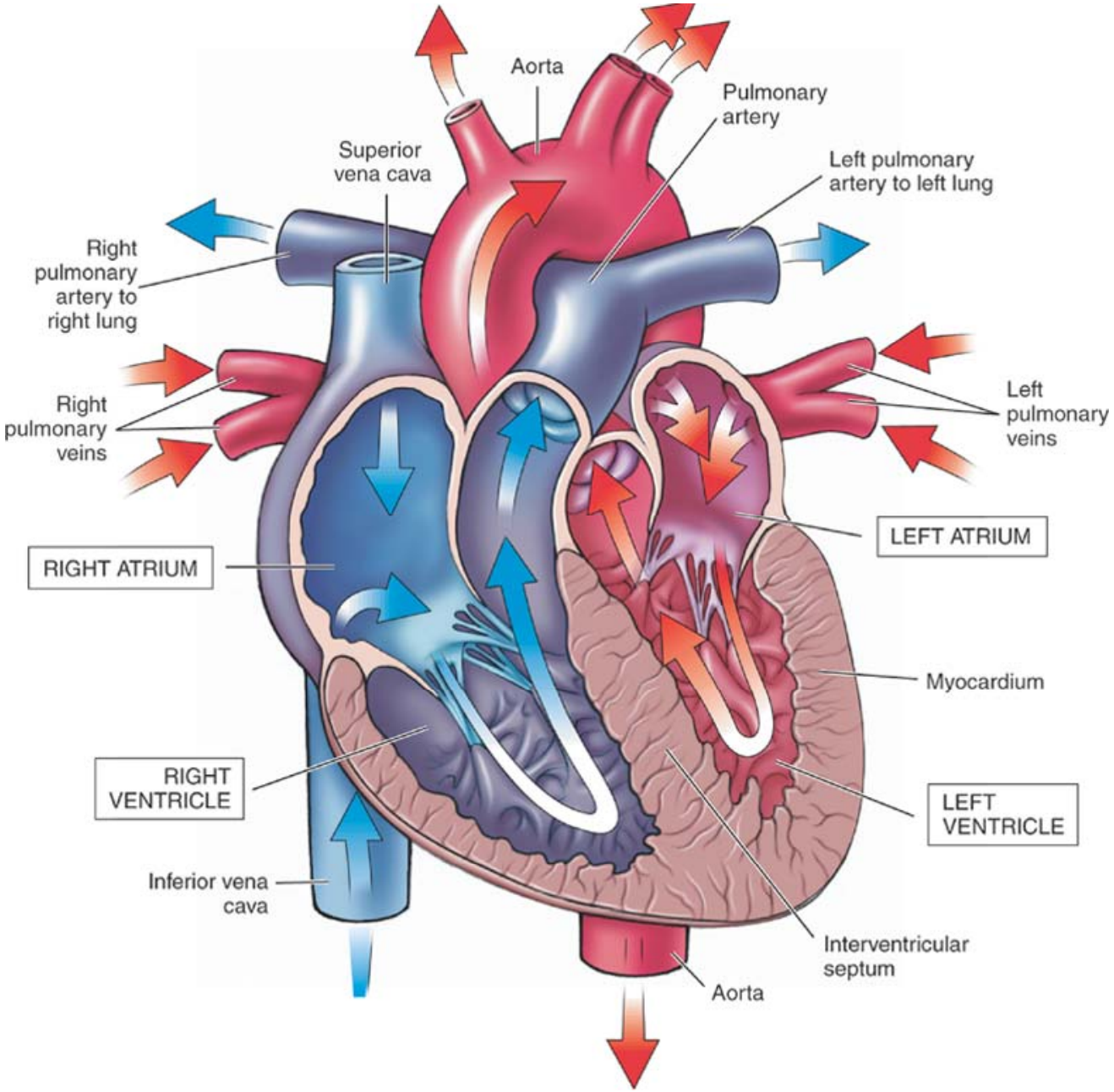
- Right Ventricle:
  - Receives deoxygenated blood from the right atrium
  - Pumps blood to lungs through the pulmonary artery
  - Pulmonary artery splits into right & left branches delivering blood to the right & left lung
  - Main function of right ventricle is to pump blood to the lungs

Chambers & Vessels

- Left Atrium:
  - Thin walled cavity
  - Receives oxygenated blood from the lungs through the 4 pulmonary veins

Chambers & Vessels

- Left Ventricle:
  - Receives oxygenated blood from the left atrium
  - Primary function is to pump blood into systemic circulation
  - Blood leaves the left ventricle through the aorta
  - Thick walled cavity needed to generate enough force to pump the blood out of the heart into systemic circulation


Aorta
Pulmonary artery
Superior vena cava
Left pulmonary artery to left lung
Right pulmonary artery to right lung
Right pulmonary veins
Left pulmonary veins
LEFT ATRIUM
RIGHT ATRIUM
Myocardium
RIGHT VENTRICLE
LEFT VENTRICLE
Inferior vena cava
Interventricular septum
Aorta

Heart Valves

- The purpose of heart valves is to keep the blood flowing in a forward direction
- 4 valves
  - 2 valves are located between the atria & ventricles are called **atrioventricular valves** or AV valves called entrance valves
  - 2 other valves are called **semilunar valves** which are considered exit valves

Heart valves

- Atrioventricular Valves:
  - Located between the atria & ventricle on each side to the heart
  - Have cusps or flaps
  - When ventricles are relaxed, cusps hang loose allowing valves to open permitting blood flow from atria to ventricles
  - When ventricles contract, the heart muscle squeezes blood into ventricles pushing cusps upward toward atria in a closed position
  - The AV valves prevent backward blood flow from the ventricles into the atria

Heart Valves

- Cusp are attached to the ventricular wall by a tough fibrous band called chordae tendineae
- As blood pushes the cusps into a closed position, the chordae tendineae are stretched to full length
- The stretched chordae tendineae hold onto the cusps & prevent them from being pushed into the atria

Heart Valves

- Right Atrioventricular Valve:
  - Called ***tricuspid valve*** because it has 3 cusps
  - Located between the right atria & right ventricle
  - When tricuspid opens, blood flows freely from the right atrium into the right ventricle
  - When the right ventricle contracts, the tricuspid valve closes preventing the blood from flowing back into the right atrium

Heart Valves

- Left atrioventricular Valve:
  - Called the bicuspid valve because it has 2 cusps
  - It is also called the mitral valve
  - Located between the left atrium & left ventricle
  - When the mitral/bicuspid valve is open, blood flows from the left atrium into the left ventricle
  - When the left ventricle contracts, the mitral/bicuspid valve closes preventing the backflow of blood into the left atrium

Heart Valves

- Semilunar Valves:
  - Considered exit valves
  - 2 types:
    - Pulmonic valve
    - Aortic valve

Heart Valves

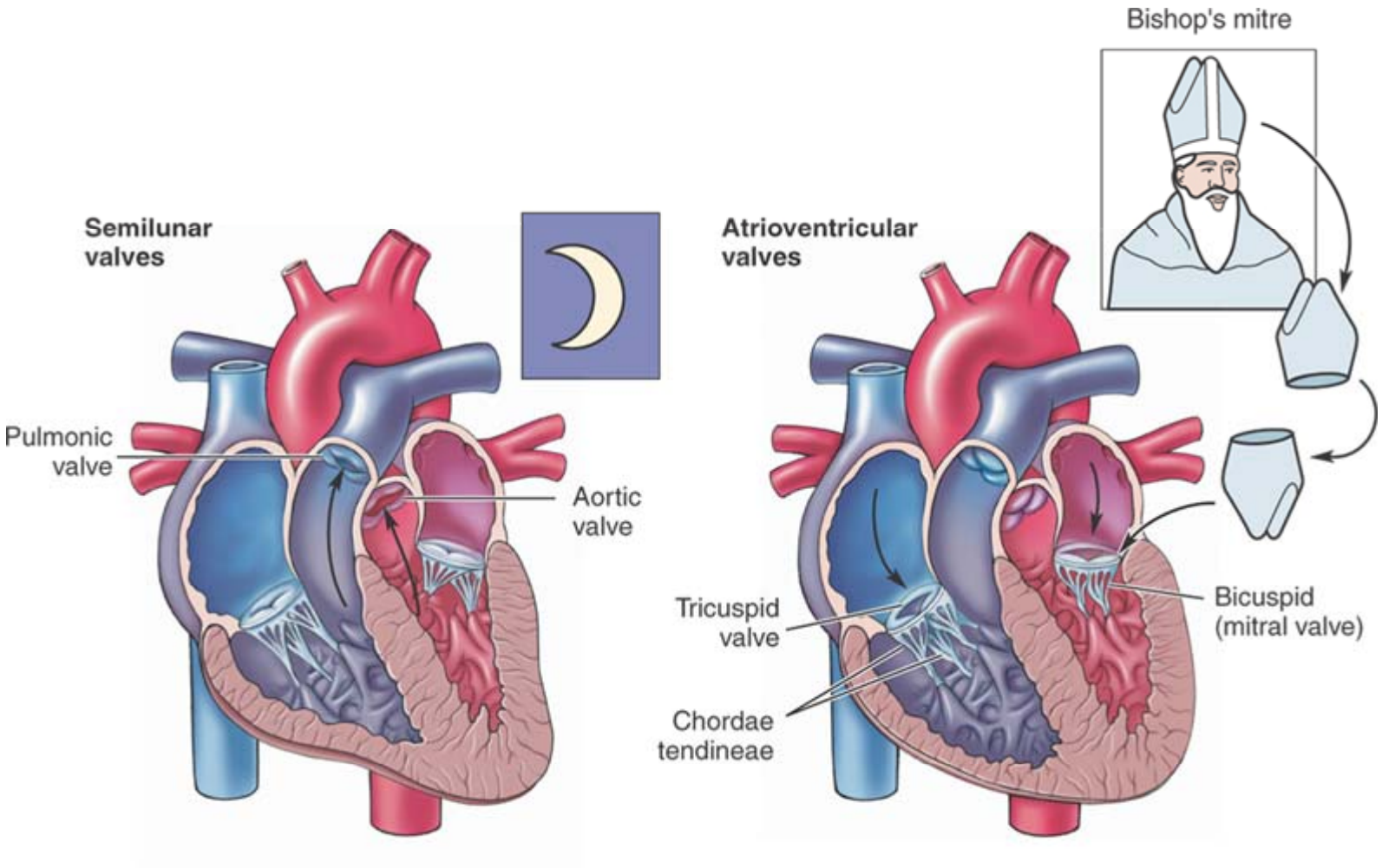
- Pulmonic Valve:
  - Also called right semilunar valve
  - Located between the right ventricle & the pulmonary artery
  - When the right ventricle relaxes, the valve is in a closed position
  - When the right ventricle contracts, blood from the ventricle forces the pulmonic valve open
  - Blood then flows through the open valve into the pulmonary artery & into the lungs
  - When the right ventricle relaxes, the pulmonic valve snaps closed & prevents the blood from returning to the right ventricle

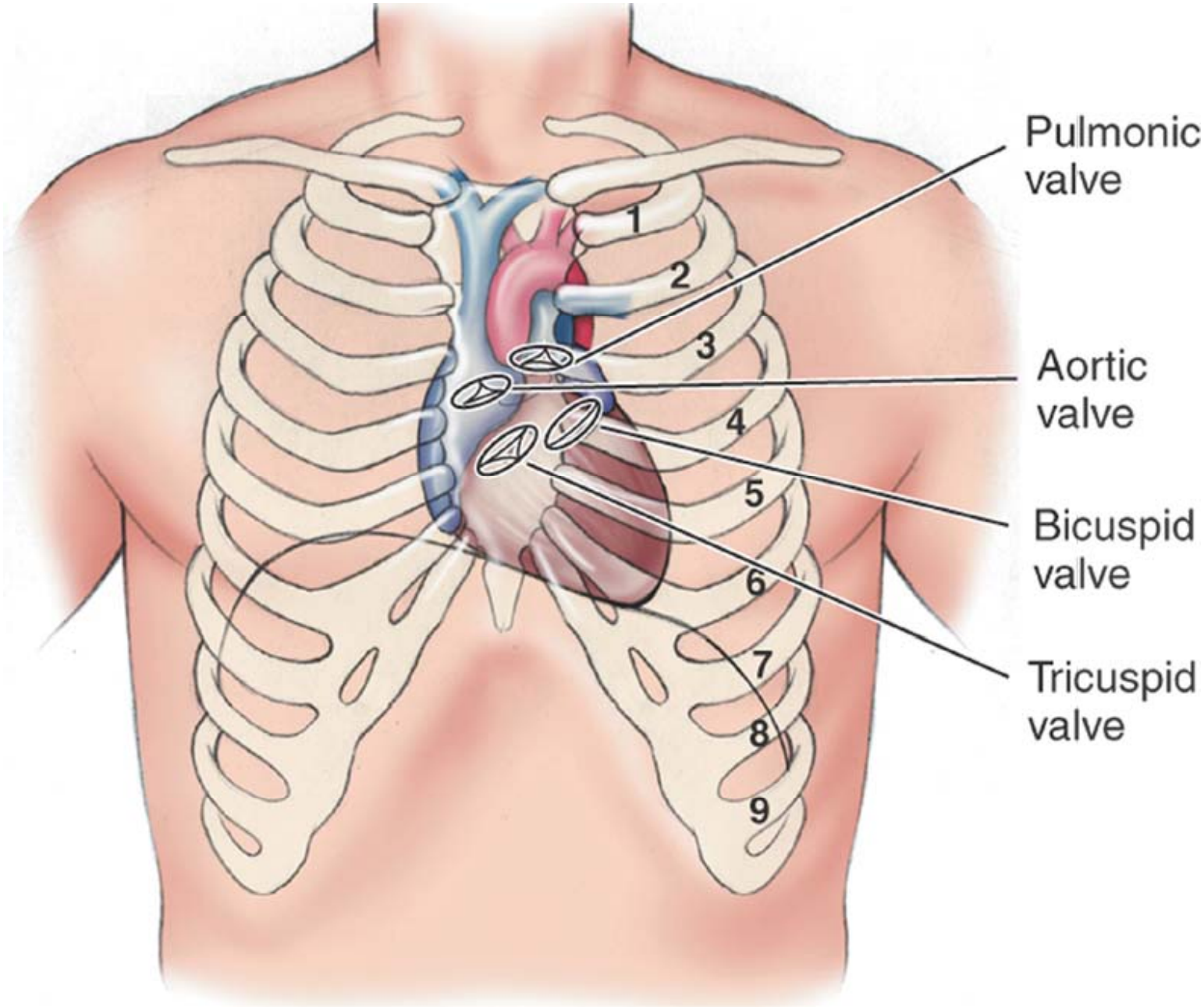
Heart Valves

- Aortic Valve:
  - Also called left semilunar valve
  - Located between the left ventricle & aorta
  - When the left ventricle relaxes, the valve is in a closed position
  - When the left ventricle contracts, blood from the ventricle forces the aortic valve to open
  - Blood flows through the aortic valve into the aorta
  - When the left ventricle relaxes, the aortic valve snaps closed preventing backflow from the aorta into the ventricle

Heart Valves

- Semilunar Valves close when the pressure in the pulmonic artery & aorta become greater than the pressure in the ventricles
- Blood from great vessels gets behind the valves & snaps them closed
- The closed semilunar valves prevent the backward flow of blood from the pulmonary artery & aorta into the ventricles


Semilunar valves
Pulmonic valve
Aortic valve
Atrioventricular valves
Bishop's mitre
Tricuspid valve
Chordae tendineae
Bicuspid (mitral valve)


Pulmonic valve
Aortic valve
Bicuspid valve
Tricuspid valve
1
2
3
4
5
6
7
8
9

Heart Sounds

- Vibrations caused by the closure of the valves are heart sounds
- The first heart sound, ***lubb,*** is due to the closure of the AV valves at the beginning of ventricular contraction
- The second heart sound, ***dupp***, is due to the closure of the semilunar valves at the beginning of ventricular relaxation
- Murmurs are abnormal heart sounds due to pathology of valves

Pathway of Blood

Unoxygenated blood enters the right atrium from the superior & inferior vena cave

↓

Right Atrium

↓

Tricuspid Valve

↓

Right Ventricle

↓

Pulmonic Valve

↓

Pathway of Blood

Pulmonary artery (right & left)

↓

Pulmonic circulation/Lungs

↓

4 Pulmonary Veins

↓

Left Atrium

↓

Pathway of Blood

Bicuspid/ Mitral Valve

↓

Left Ventricle

↓

Aortic Valve

↓

Aorta

↓

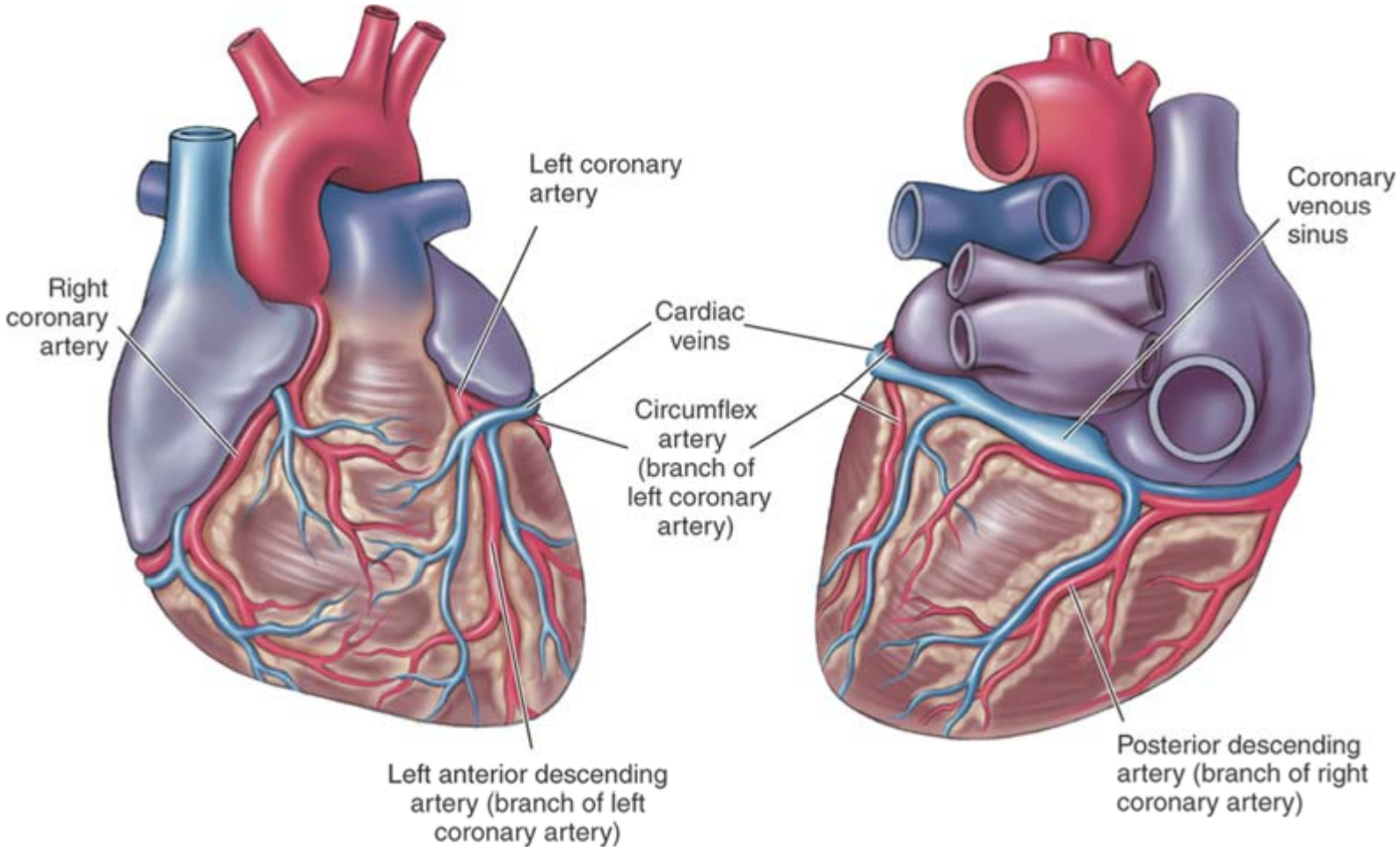
Systemic Circulation

Myocardium Blood Supply

- The myocardium of the heart receives its blood supply from the coronary arteries
- Coronary arteries arise from the aorta just above the aortic valve
- Two main arteries are:
  - Left & Right coronary artery

Coronary Arteries

- Right coronary artery nourishes the right side of the heart, esp. Right ventricle
- Left coronary artery branches into the left anterior descending artery & the circumflex artery which nourish left side of heart, esp. Left ventricular wall
- Coronary veins collect blood that nourishes the myocardium & carries it to the coronary sinus which empties into the right atrium


Left coronary artery
Right coronary artery
Cardiac veins
Circumflex artery (branch of left coronary artery)
Coronary venous sinus
Left anterior descending artery (branch of left coronary artery)
Posterior descending artery (branch of right coronary artery)

Cardiac Conduction System

- An electrical signal stimulates the heart muscle to contract & coordinates the pumping activity of the atria & ventricles
- Both atria contract at same time followed by simultaneous contraction of both ventricles
- The conduction system is located in the walls of the heart & in the septum that separates the right & left heart

Cardiac Conduction System

- Conduction System consists of:
  - Sinoatrial node
  - Atrial conducting fibers
  - Atrioventricular node
  - Bundle of His
  - Purkinje System

Cardiac Conduction System

- Sinoatrial Node:
  - Pacemaker of the heart
  - Located in the upper posterior wall of the right atrium
  - Electrical signal called cardiac impulse starts in the SA node
  - SA node fires 60-100 cardiac impulses/minute (average 72)

Cardiac Conduction System

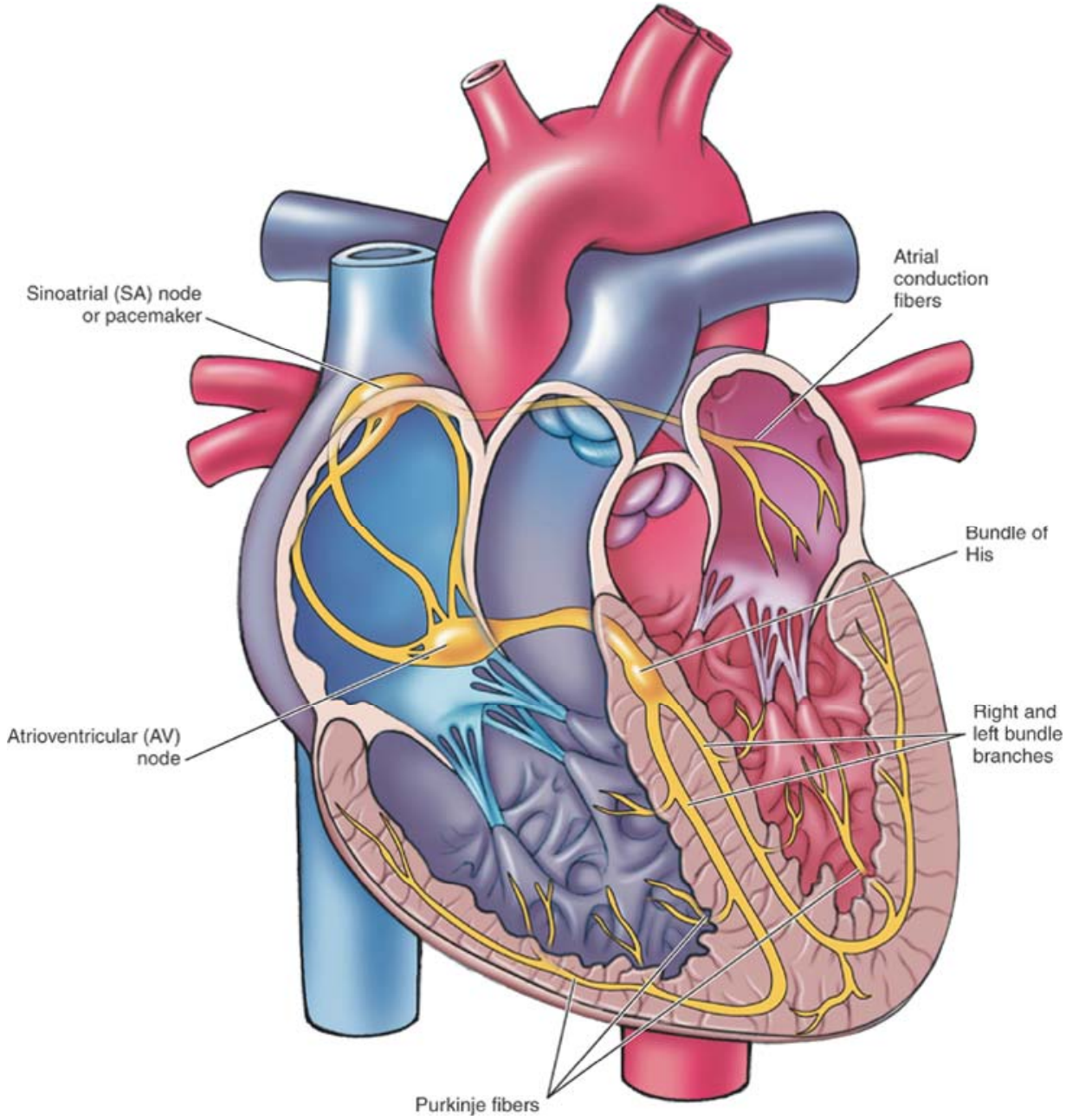
- Atrial Conducting Fibers
  - Cardiac impulse travels from the SA node through both atria along the atrial conducting fibers
- Atrioventricular Node:
  - Located in the floor of the right atrium, near the interatrial septum
  - Cardiac impulse travels from the SA node across the atrial fibers to the AV node

Cardiac Conduction System

- Bundle of His:
  - Once the impulse moves through the AV node it slows & travels to the Bundle of His
  - Bundle of His is specialized conduction tissue located in the interventricular septum
  - The slowing of the impulse through the AV node delays ventricular activation which allows the relaxed ventricle to fill with blood after the atrial contraction

Cardiac Conduction System

- Bundle of His:
  - Two branches:
    - Right & Left Bundle Branches
  - Along these branches are numerous long fibers called Purkinje Fibers
  - Purkinje Fibers are distributed throughout the ventricular myocardium & conduct cardiac impulses very rapidly throughout the ventricles ensuring coordinated contraction of both ventricles


Sinoatrial (SA) node
or pacemaker
Atrial
conduction
fibers
Bundle of
His
Atrioventricular (AV)
node
Right and
left bundle
branches
Purkinje fibers

Sinoatrial Node

↓

Atrial conducting fibers

↓

Atrioventricular Node

↓

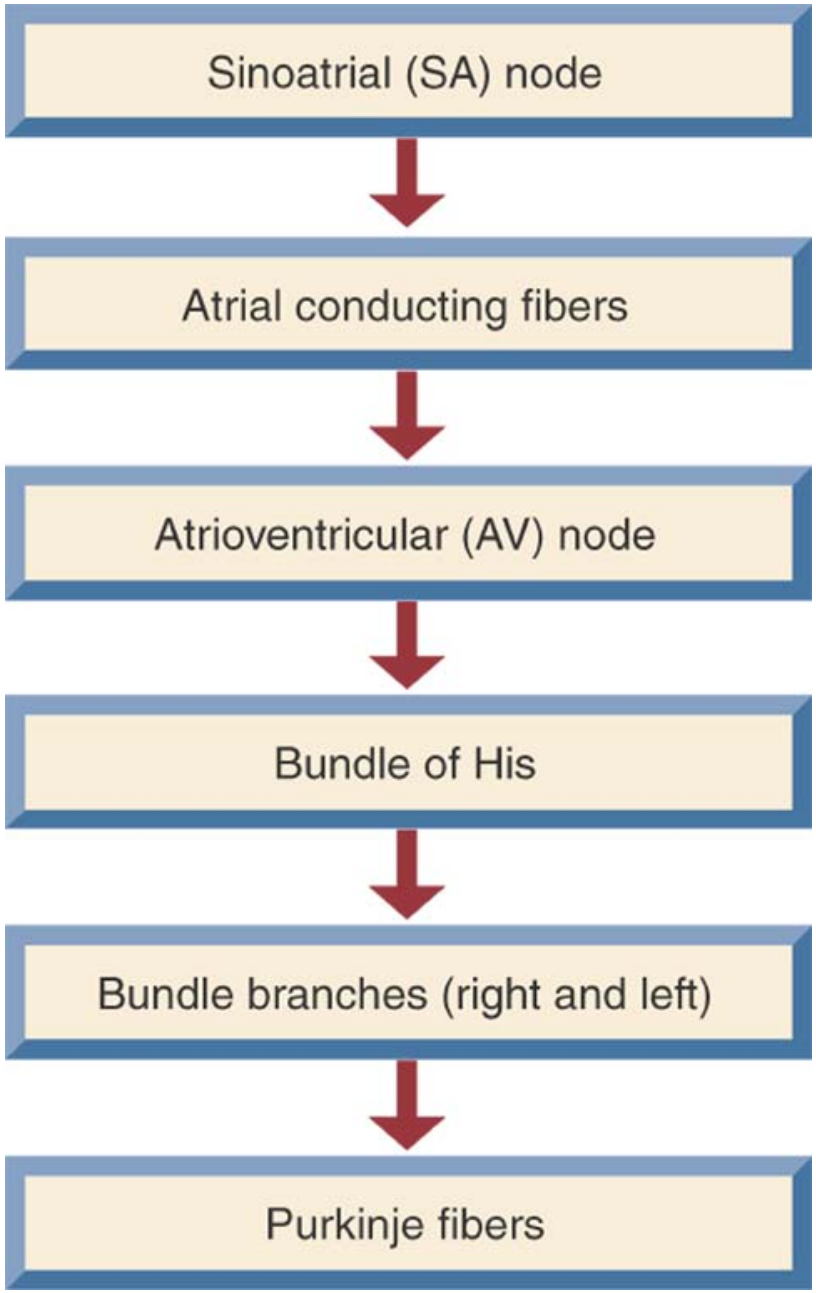
Bundle of His

↓

Bundle Branches(right & left)

↓

Purkinje Fibers


Sinoatrial (SA) node
Atrial conducting fibers
Atrioventricular (AV) node
Bundle of His
Bundle branches (right and left)
Purkinje fibers

Cardiac Tissue

- Cardiac tissue creates impulses because of:
  - automaticity & rhythmicity
- Automaticity: cardiac impulses arise within the cardiac tissue itself; no extrinsic nerve or factors
- Rhythmicity: cardiac impulses are fired regularly; the heart has rhythm

Wandering Pacemaker

- When an impulse is fired from an area outside the SA node, it is said to be a wandering pacemaker
- Called ectopic focus because it causes an ectopic beat
- At times the AV node will fire a cardiac impulse
- When an impulse comes from an area other than the SA node it can cause serious dysrhthymias

Electrocardiogram

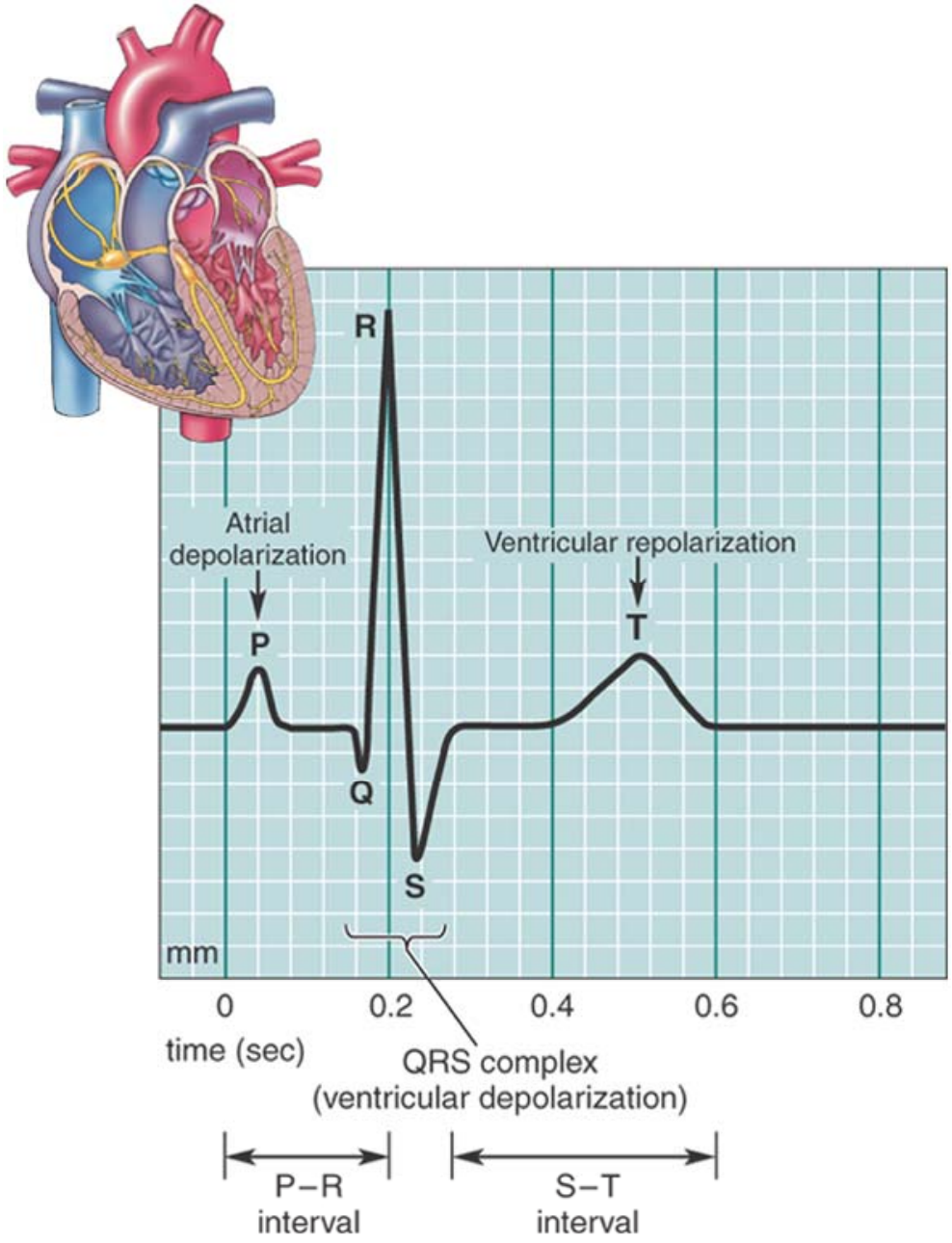
- Electrical activity of the heart can be measured by placing electrodes on the surface of the chest & performing an Electrocardiogram
- Components of test include:
  - P wave
  - QRS complex
  - T wave
  - P-R interval

Electrocardiogram

- P Wave:
  - Atrial depolarization
  - Inflow of sodium ions make the inside of the cell positive
  - Depolarization precedes & triggers contraction of the heart muscle
- QRS complex:
  - Reflects the electrical activity related to ventricular depolarization

Electrocardiogram

- T wave:
  - Reflects electrical activity related to ventricular repolarization; return of the cell to a resting state where the inside is negative
- P-R interval
  - Represents the time it takes for the cardiac impulse to travel for the atria (P wave) to the ventricles (QRS complex)


R
Atrial
depolarization
Ventricular repolarization
P
T
Q
S
mm
0
0.2
0.4
0.6
0.8
time (sec)
QRS complex
(ventricular depolarization)
P–R
interval
S–T
interval

Cardiac Cycle

- Cardiac Cycle
  - is the sequence of events that occur during one heart beat
  - Coordinated contraction & relaxation of the chambers of the heart
- Systole:
  - Contraction of the heart muscle
  - Systole squeezes blood out of a chamber
- Diastole:
  - Relaxation of the myocardium
  - During diastole blood fills the chambers

Cardiac Cycle

- Atrial Systole:
  - Atria contract & blood is pumped into ventricles; AV valves are open & ventricles are relaxed
- Ventricular Systole:
  - At the end of atrial systole, the ventricles contract
  - Blood is forced against the AV valves causing them to close
  - Blood is pushes the semilunar valves open allowing blood to flow into pulmonary artery & aorta

Cardiac Cycle

- Diastole:
  - For a brief period during the cardiac cycle, both the atria & ventricles are in diastole
  - As the chambers relax, blood flows into the atria
  - Since the AV valves are open much of the blood passively flows into the ventricle
  - This is a period of filling
  - Atrial systole follows
  - The cycle repeats

Cardiac Output

- Cardiac output is the amount of blood pumped by each ventricle in 1 minute
- Normal output is 5 liters per minute
- The entire blood volume pass through the heart every minute
- Cardiac output is determined by two factor:
  - Heart rate & Stroke Volume
- CO = HR x SV
- Cardiac output can be increased by increasing the HR &/or SV

Heart Rate

- Heart rate:
  - Is the number of times the heart beats in a minute
  - Reflects the firing of the SA node
  - Normal adult HR is 60-100
  - Average 72
  - Heart rate differs for various reasons:
    - Size—gender—age—exercise—hormones—stimulation of automonic nervous system—pathology—medication

Heart Rate

- Size: larger the size, the slower the rate; related to metabolism
- Gender: women's are faster than men
- Age: the younger the person, the faster the rate
- Exercise: increase in activity causes and increase in HR; pulse less at rest
- Autonomic nervous system: stimulation of sympathetic increases HR; stimulation of parasympathetic slows the HR

Heart Rate

- Hormonal influence:
  - Epinephrine & norepinephrine
  - Thyroid hormone
- Pathology:
  - Issues within cardiac conduction itself
- Medications:
  - Certain drugs affect the HR

  Digitalis ↓ HR Caffeine ↑ HR
- Variation in Heart Rate
  - Tachycardia: HR greater than 100
  - Bradycardia: HR less than 60

Stroke Volume

- Stroke volume is the amount of blood pumped by the ventricle per beat
- Average resting stroke volume is 60-80 ml per beat
- The ventricles normally pump out only 65% of the blood in the ventricles
- Greater force of contraction can increase stroke volume & the greater amount of blood pumped in one minute
- Two ways stroke volume can be affected:
  - Starling's law & Inotropic effect

Starling's Law

- Starling's law of the heart depends on the degree of stretch of the myocardial fibers
- The greater the stretch, the stronger the force of contraction
- Increase in the amount of blood entering the ventricles causes the ventricles to stretch
- This stretch increases the force of contraction
- Increase in force of contraction will increase stroke volume

Inotropic Effect

- Positive inotropic effect:
  - stimulation of heart by the sympathetic nerves can increase force of contraction therefore increasing stroke volume
  - Certain hormones & medications can also do this
- Negative inotropic effect:
  - Decreases force of contraction which decreases stroke volume
  - Pathology of the heart & certain medications can cause negative inotropic effect