Cardiovascular Anatomy

DND Primary Care Paramedicine

Module: 04

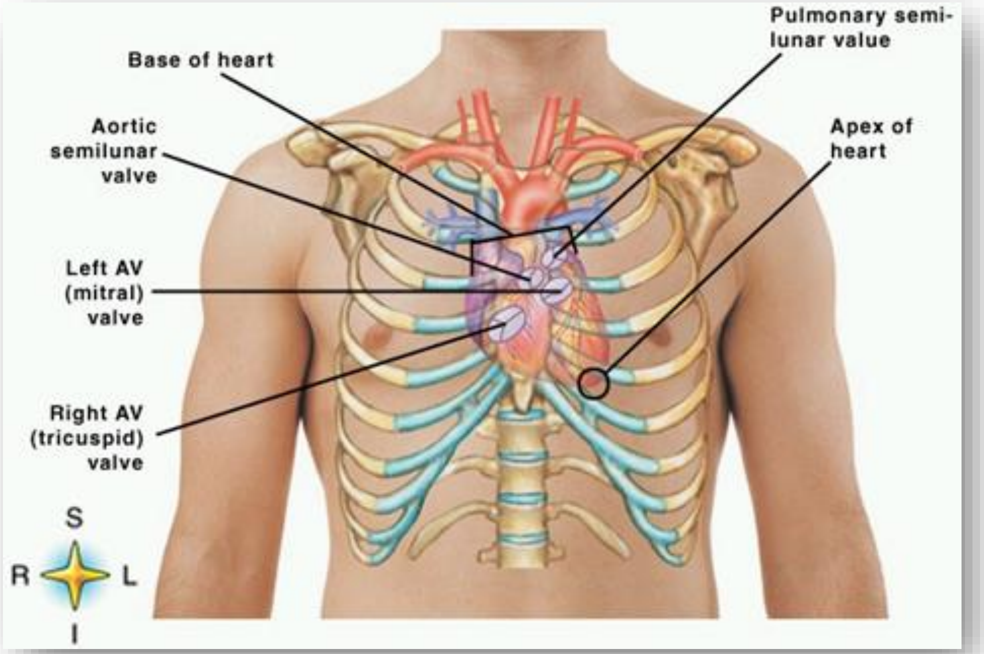
Section: 01

The Cardiovascular System

- Contains the organs for circulation
- Includes:
  - Heart
  - Vessels
    - Veins
    - Arteries
    - Capillaries
  - Blood
- Is a closed system

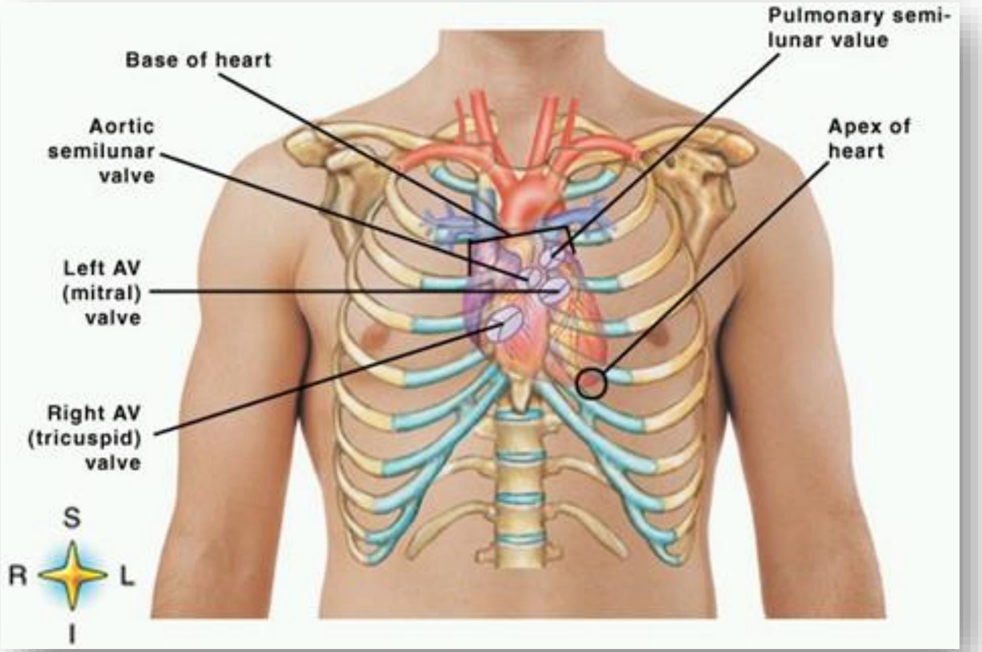
The Heart

- Two muscular pumps
- Provides the necessary force to circulate the blood to the tissues
- On average the adult heart pumps 5 L/min



The Heart

- Located in the mediastinum:
  - Posterior to the sternum
  - Rests on diaphragm, 2/3 left of midline
  - The apex is directed inferiorly, anteriorly and to the left (5th intercostal space)
  - The base has several large vessels attached and extends to the 2nd intercostal space
  - On average 9 - 12 cm long



Pericardium

- 2 layer sac that covers the heart
- Fibrous pericardium
  - Outer layer formed of tough white fibrous connective tissue
  - Attached to the large vessels at the base of the heart, diaphragm, sternum and vertebrae
- Serous pericardium
  - Fibrous layer lined with serous membrane called parietal pericardium
  - Inner layer is visceral pericardium (epicardium)
  - Potential space between them is the pericardial cavity
  - Contains pericardial fluid (10 – 15 ml) secreted by the serous membranes

Heart Wall

- 3 distinct layers
  - Epicardium
  - Myocardium
  - Endocardium

Epicardium

- Outer layer firmly anchored to the underlying muscle
- Thin protective layer
- Vessels that nourish the heart are located here

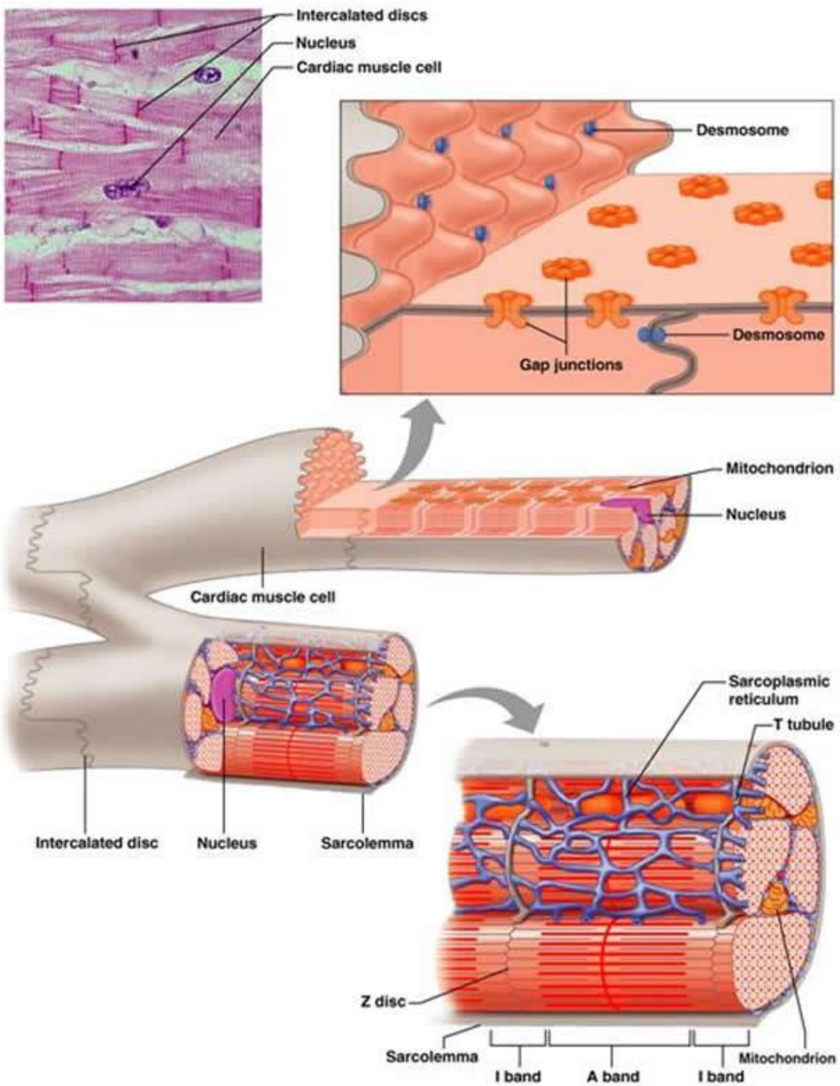
Myocardium

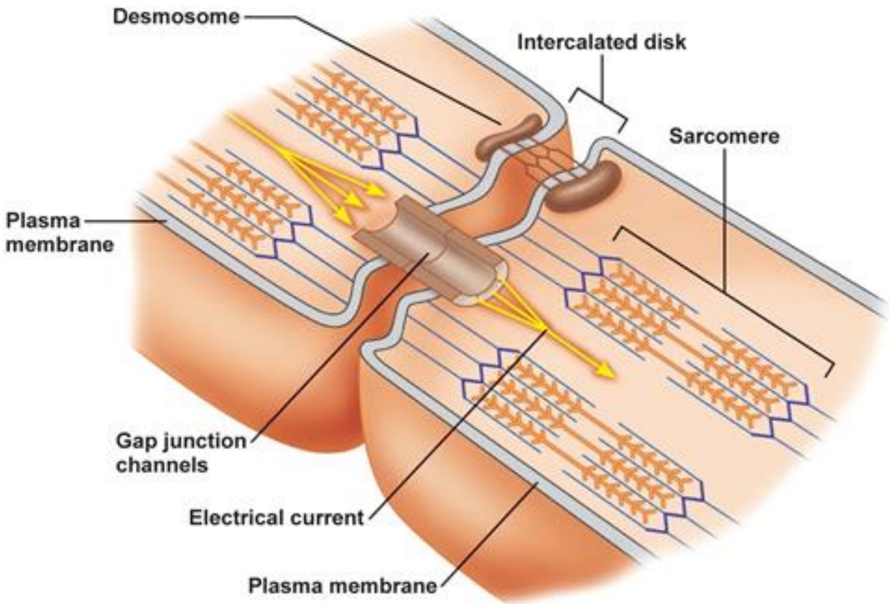
- Thick middle layer formed of special cardiac tissue
  - Have the following characteristics
    - Electrical Cells
      - Automaticity
        - » The ability to spontaneously generate and discharge an electrical impulse
      - Excitability
        - » The ability of the cell to respond to an electrical impulse
      - Conductivity
        - » The ability to transmit an electrical impulse from one cell to the next
    - Myocardial Cells
      - Contractility
        - » The ability of the cell to shorten and lengthen its fibers
      - Extensibility
        - » The ability of the cell to stretch
  - Can not summate contractions (tetanus) so do not fatigue

Myocardium

- Branching cells are connected by intercalated discs
- Each disc contains many gap junctions allowing for large amounts of cardiac muscle to be coupled into a single unit (syncytium)
- This allows for action potential to be passed along a large area of the heart wall
- Wrap around the heart in a spiral fashion

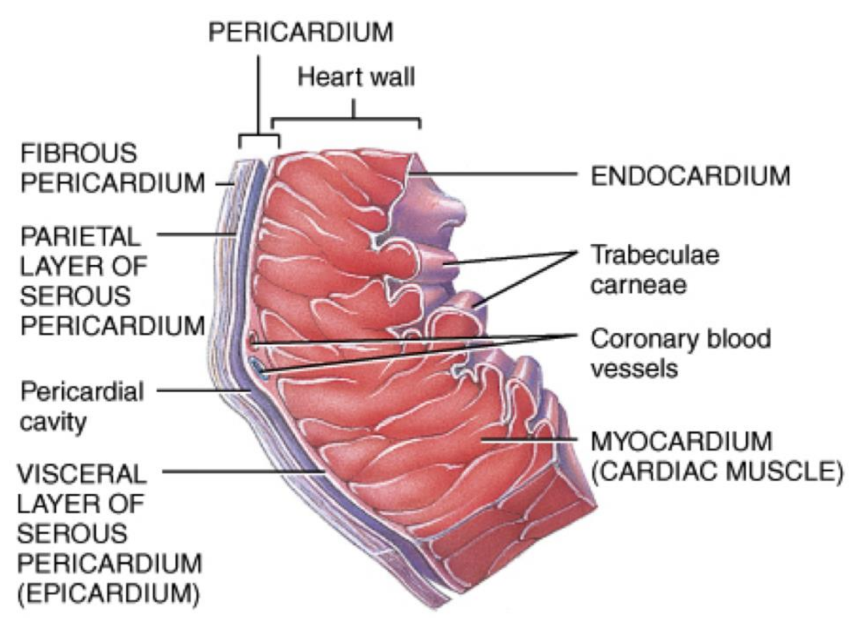
Intercalated Discs





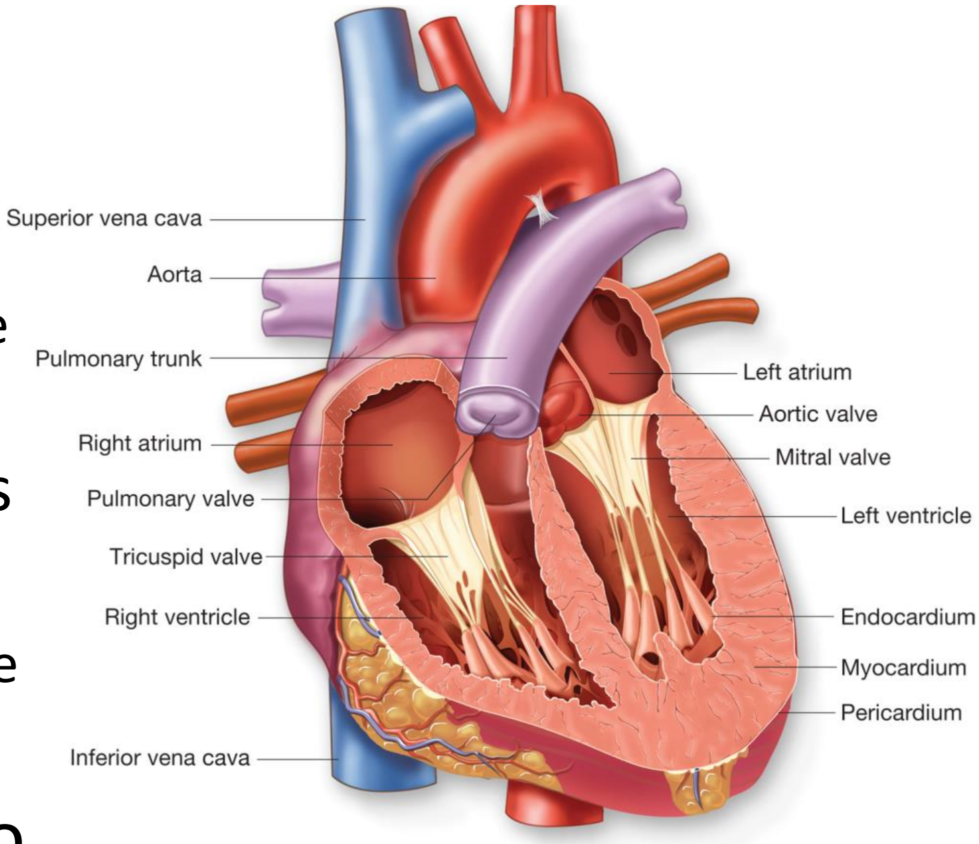
Endocardium

- Inner smooth endothelium layer
- Also forms the valves of the heart
- Is continuous with the lining of the blood vessels
- Contains muscular projections called Trabeculae
- Help regulate flow of blood through chambers



Chambers

- Four chambers
  - Right and left atria
    - Thin walled chambers
    - Receives blood form the veins
  - Right and left ventricles
    - Thick walled chambers
    - Sends blood through the arteries
- Separated from right to left by the septum



Atria

- Receives blood from the veins
- Myocardial layer is thin
- Both atria have small extensions called auricles
- Are divided by Rt to Lt by interatrial septum
  - A thin region, the fossa ovalis, of the interatrial septum represents the foramen ovale that existed during the fetal stage
- Right Atrium
  - Receives deoxygenated blood from the inferior and superior vena cava as well as the coronary sinus
- Left Atrium
  - Receives oxygenated blood from the lungs through the four pulmonary veins

Ventricles

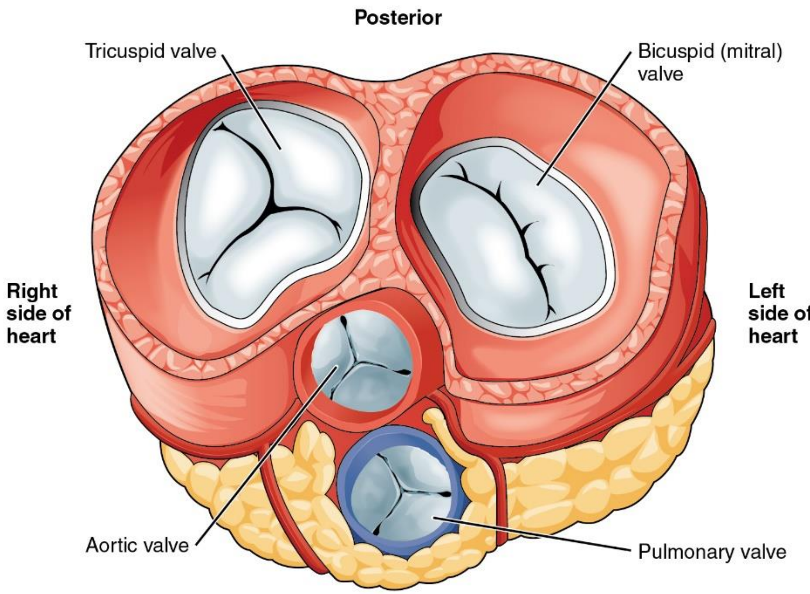
- Receives blood from the atria above
- Thicker myocardial layers (left is thickest)
- Are divided by interventricular septum
- Also have papillary muscles projecting from the wall
- Right Ventricle
  - Receives deoxygenated blood from the right atrium and pumps it to the lungs
- Left Ventricle
  - Receives oxygenated blood from the left atrium and pumps it to the body

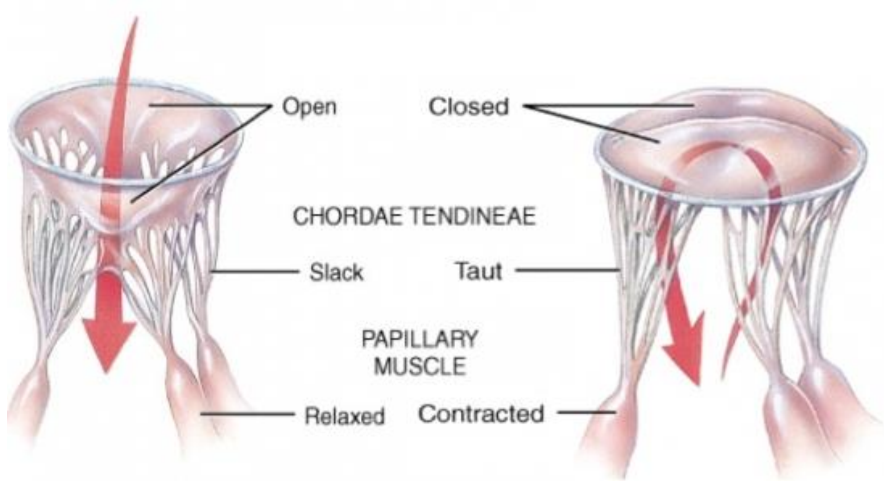
Heart Valves

- Mechanical devices that permit the flow of blood
  - Atrioventricular valves (cuspid valves)
  - Semilunar valves

Atrioventricular Valves

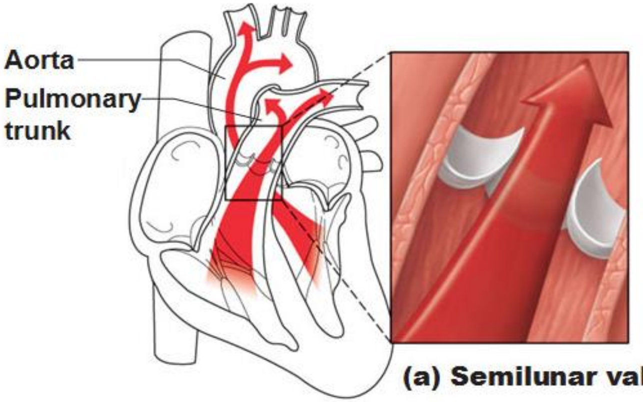
- Between the atrium and the ventricles
  - Tricuspid valve (right)
  - Bicuspid (mitral) valve (left)
- Free edges are attached to papillary muscles by chordae tendineae
- Forced open as blood returns to atria, and closed when the ventricles contract



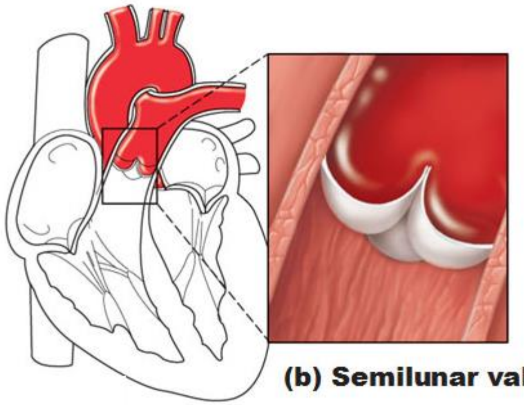


Semilunar Valves

- Located at the bases of the large vessels attached to the ventricles (aorta and pulmonary artery)
- Half-moon flaps grown from the linings of the large vessels
- Open as pressure increases with contraction of the ventricles and forced closed as blood flows back into the "cups"



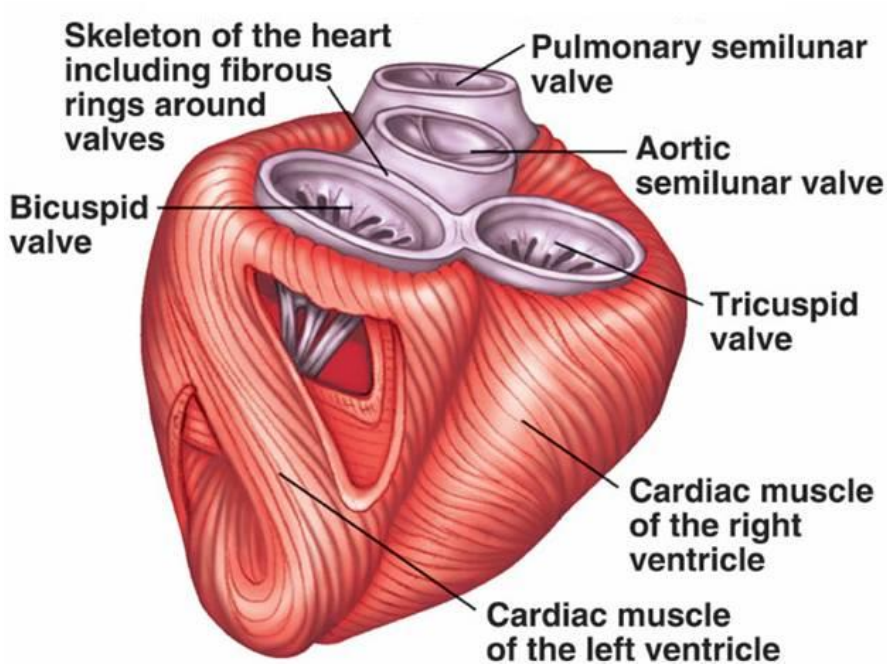
(a) Semilunar valves open



(b) Semilunar valves closed

Skeleton

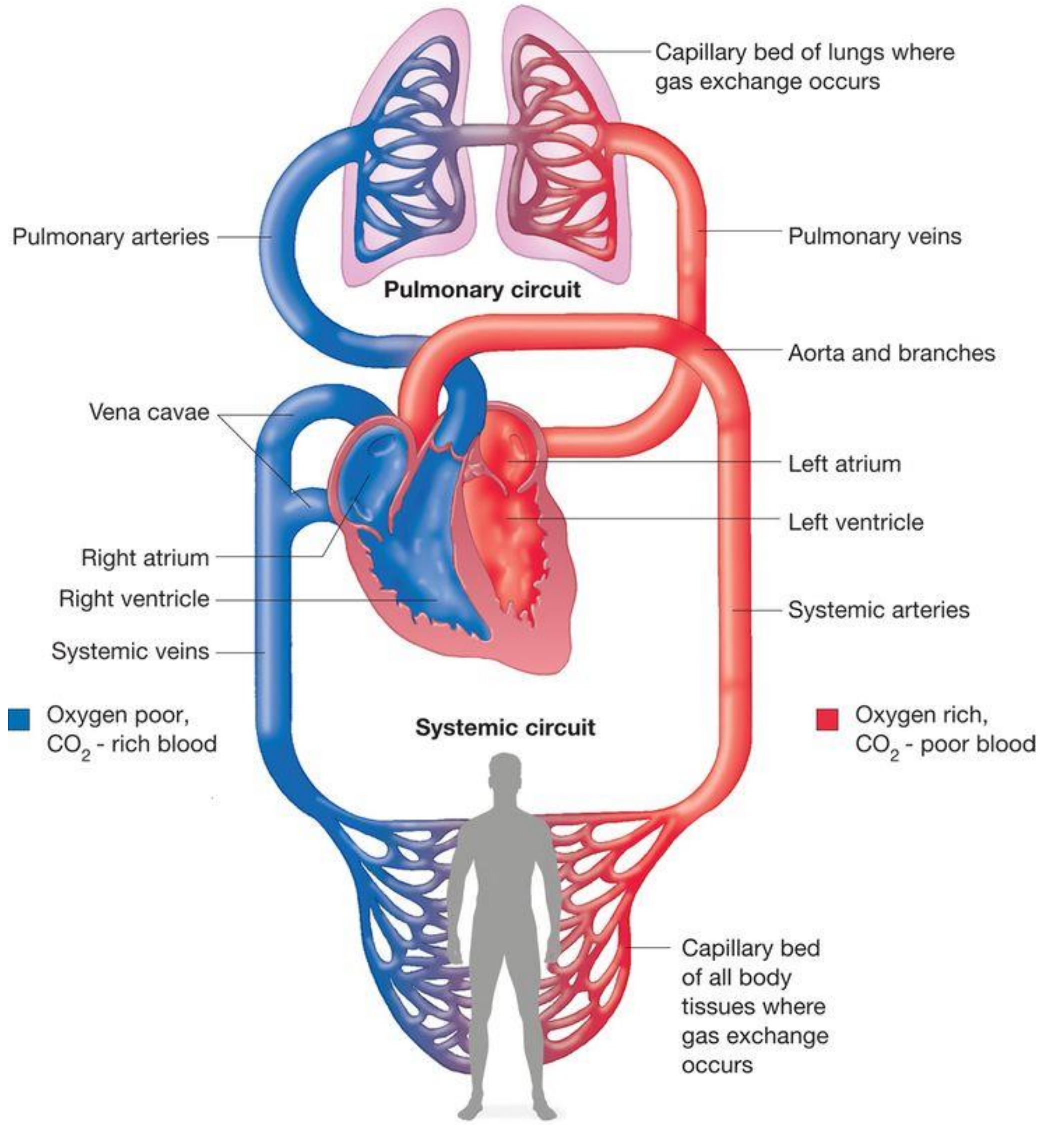
- Fibrous structure
- Connective rings serving as support for the heart valves and point of attachment for myocardium
- Also serves as an electrical barrier



Flow of Blood

- Right Pump (Pulmonary Circulation)
  - Blood returns to the RA from systemic circulation
  - Passes the tricuspid valve and enters the RV
  - RV sends blood to the lung to be oxygenated through the pulmonary SL valves into the pulmonary arteries
- Left Pump (Systemic Circulation)
  - Returns from lungs through pulmonary veins into LA
  - Passes Mitral valve into the LV
  - Passes the aortic SL valve into the ascending aorta to the body

Flow of Blood

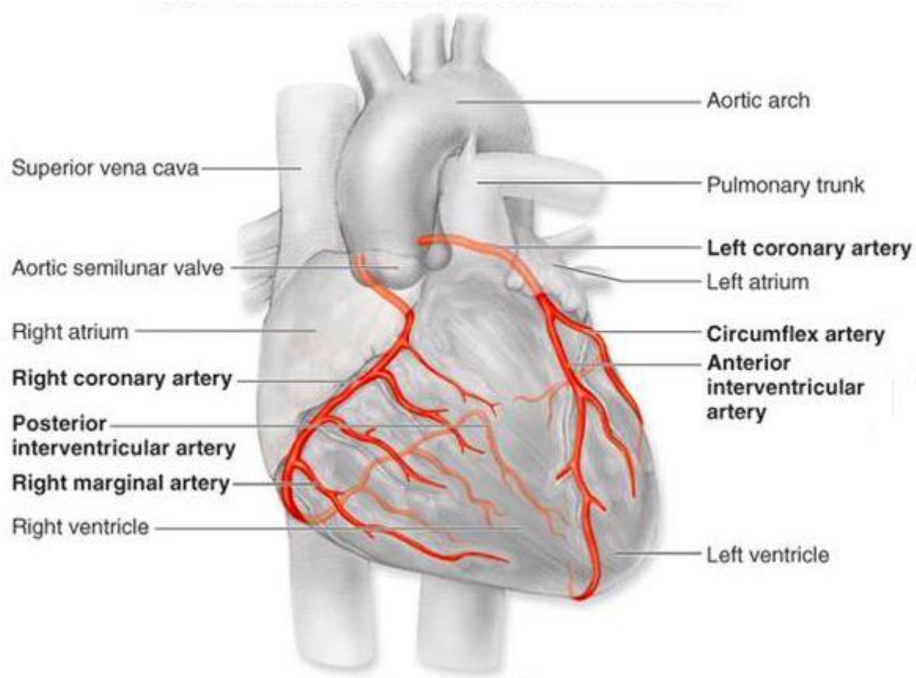


Blood Supply of the Heart Tissue

- Two main coronary arteries branch from the ascending aorta
- Lies behind the flaps of the SL valves
- Blood flow is greatest when the heart is at rest, compression of the ventricles reduces flow
- Arteries have numerous branches and anastomoses to allow for collateral blood flow (collateral circulation)

Blood Supply of the Heart Tissue

- Right Coronary Artery
  - Continues to the Right AV sulcus and to the posterior portion of the heart
  - Supplies most of the right ventricle



- Left Coronary Artery
  - Extends left for 2 cm then divides
    - Anterior interventricular (descending) artery (Aka LAD)
    - Circumflex artery (which continues around to the posterior portion of the heart)

Blood Supply of the Heart Tissue

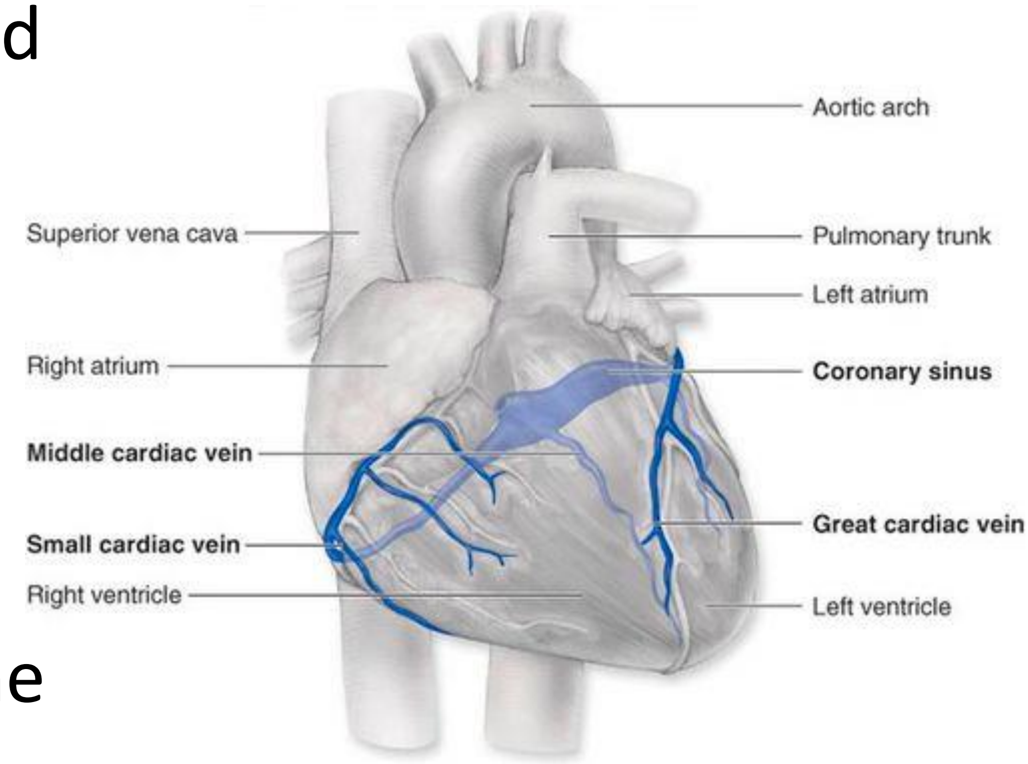
- Both ventricles receive blood from branches of the Rt and Lt coronary arteries
- Atrium receive blood from corresponding artery
- Coronary artery dominance

Coronary Artery	Cardiac Muscle	Conduction System
RCA	RV-lateral/posterior wall LV-inferior wall	SA node (45%)* AV node (90%)* Bundle of His Right Bundle
LAD	RV-anterior wall LV-septum/apex/ anterior wall	Left Bundle
LCx	LV-lateral/posterior wall	Left Bundle SA node (55%)* AV node (10%)*

* Represents the percentage of the population in which this feature occurs.

Blood Supply of the Heart Tissue

- After blood has passed through capillaries returns through the coronary veins
- They lie next to the coronary arteries
- Most drain into the coronary sinus into the right atrium
  - Some in the RV drain directly into the RA

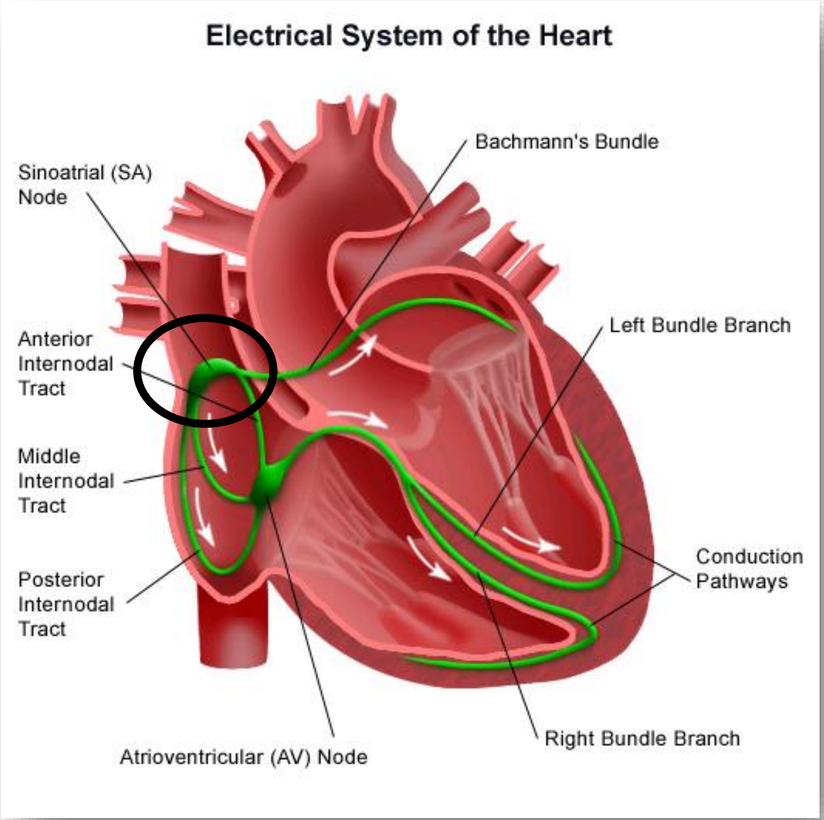


Conduction System

- Composed of
  - Sinoatrial node
  - Atrioventricular node
  - Atrioventricular bundle
  - Purkinje fibers
- Specialized cardiac cells
  - Differ in function where they conduct as well as of conduct for contraction

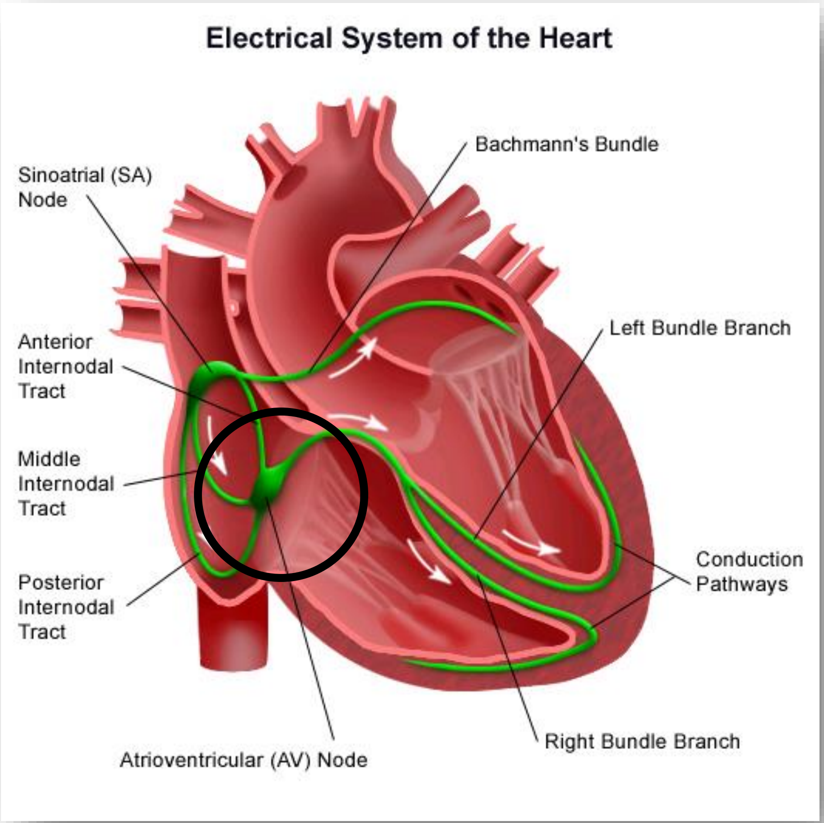
SA Node

- Consists of hundreds of cells near the opening of the Superior VC
- Intrinsic rate of 60 - 100 bpm
- Establishes basic rhythm, known as the pacemaker
- Impulses rapidly transfer to the atrium and cause them to contract and to the AV Node



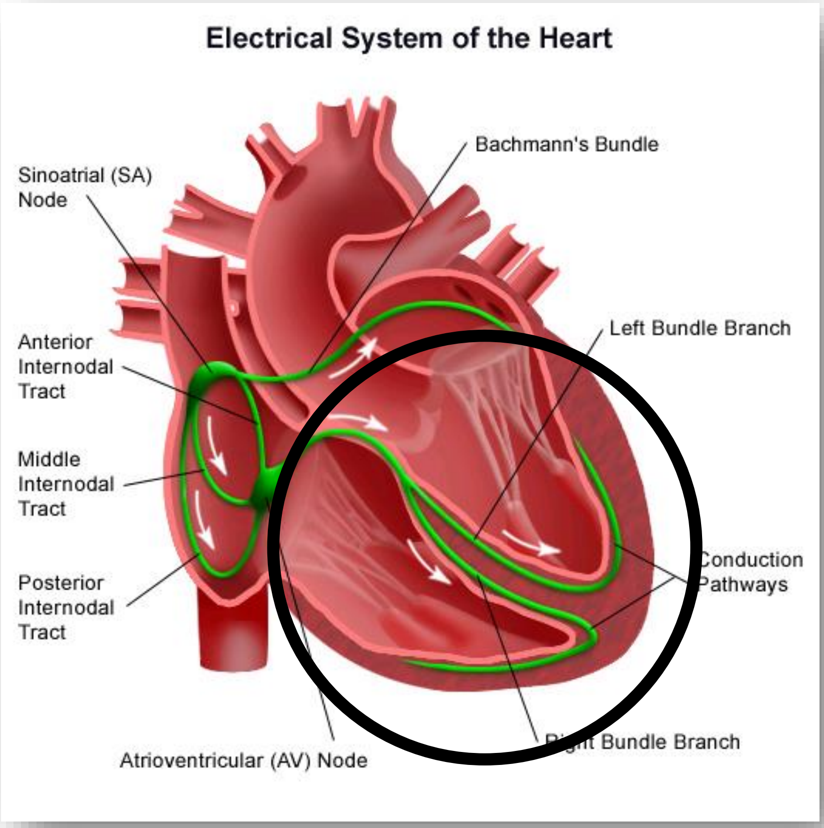
AV Node

- Also known as the Node of Tawara
- Located on the floor of the Right Atrium along the Interatrial septum
- Intrinsic value of 40 - 60 bpm
- Conducts impulse slower so gives a slight delay which allows for the atria to finish contracting



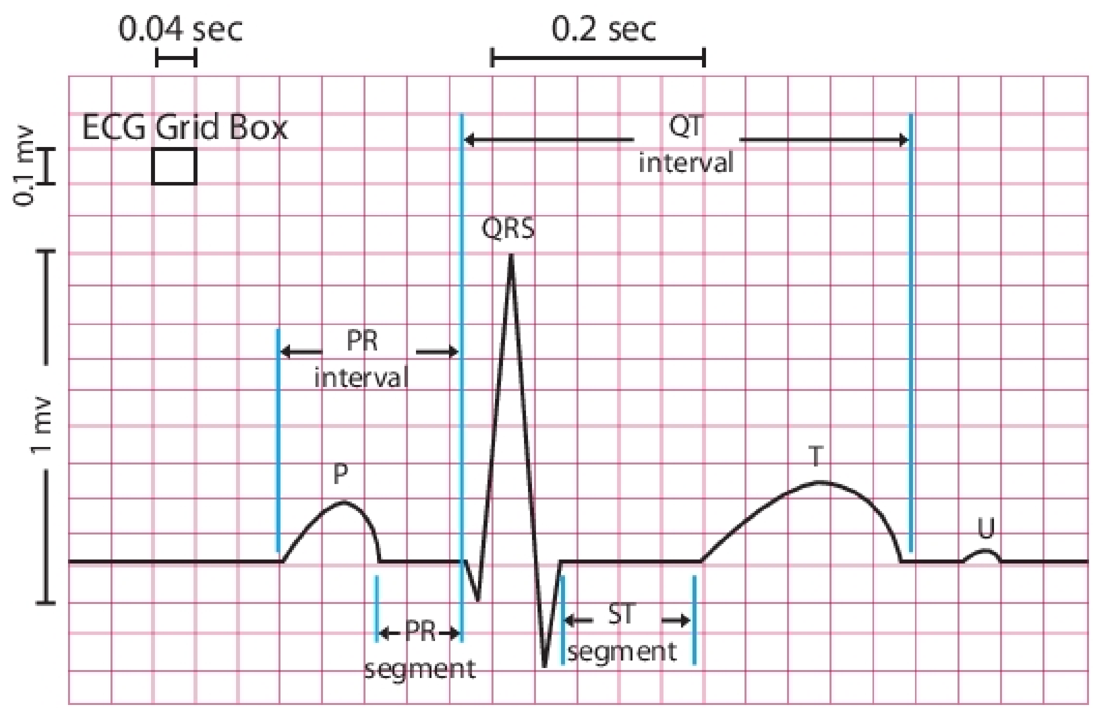
AV Bundle and Purkinje Fibers

- A bundle of specialized cardiac fibers extending from the AV node
- Extends by two branches down either side of the Interventricular septum
- Impulse moves rapidly through the AV bundle to the right and left bundle branches
- The bundle branches extend along the walls of the ventricles and papillary muscles
- Branch off to form the conducting myofibers (purkinje fibers)



The ECG

- A graphically representation of the heart's electrical activity
  - P Wave
  - QRS Complex
  - T Wave
  - U Wave



Nerve Supply

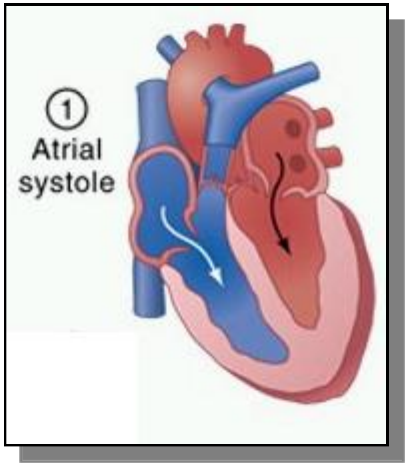
- Sympathetic
  - Contained in the middle, superior and inferior cardiac nerves
- Parasympathetic
  - Vagus nerve
- Combine to form cardiac plexus at the arch of the aorta
- Extend from the plexus accompany coronary arteries to enter the heart
- Terminate in the
  - SA node
  - AV node
  - Atrial myocardium

Cardiac Cycle

- A complete pumping cycle (heartbeat)
- Combination of systolic and diastolic phases (0.8 seconds)
- The five steps of a full cycle
  - Atrial systole
  - Isovolumetric ventricular contraction
  - Ejection
  - Isovolumetric ventricular relaxation
  - Passive ventricular filling

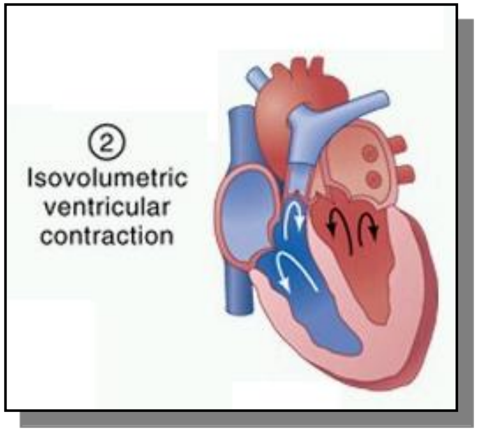
Atrial Systole

- AV valves are open
- Ventricles are relaxed
- Depolarization of atrial myocardium completes the emptying of the atria (atrial kick – accounts for 20% of blood volume)
  - Atrial systole (0.1 seconds)
- SL valves are closed
- Coincides with the P wave



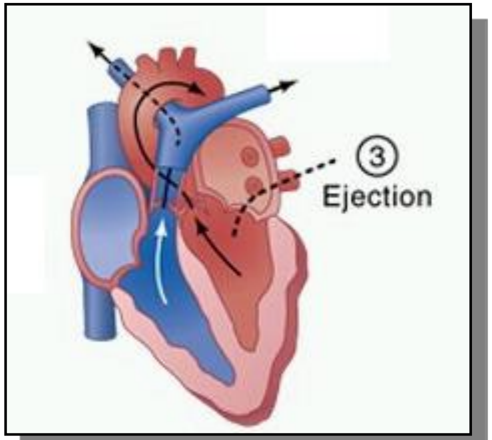
Isovolumetric Ventricular Contraction

- AV Valves close
- Period between ventricular systole and the opening of the SL valves
- Volume remains constant as the pressure increases
  - Increase is from contraction of ventricular myocardium
- Coincides with the R wave
- Appearance of the first heart beat sound



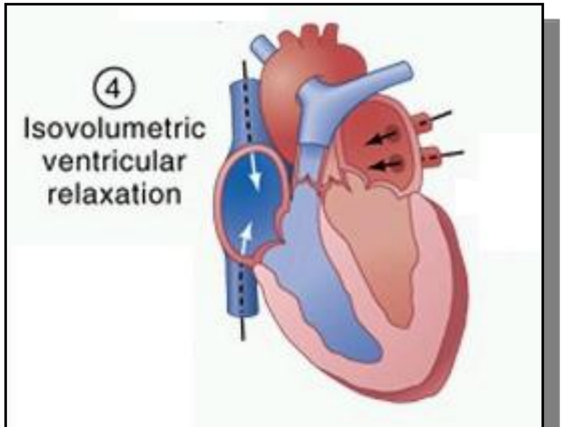
Ejection

- SL valves open once the interventricular pressure exceeds the pulmonary artery and aorta pressures
  - Rapid ejection
    - Initial short phase
    - Marked by increase in pressures and an increase in aortic blood flow
  - Reduced ejection
    - Longer phase
    - Marked by decrease in ventricular emptying
  - Residual volume
    - Quantity of blood remaining in the ventricle at the end of the ejection phase



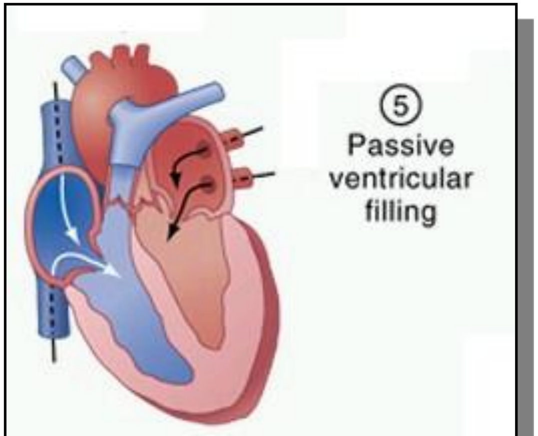
Isovolumetric Ventricular Relaxation

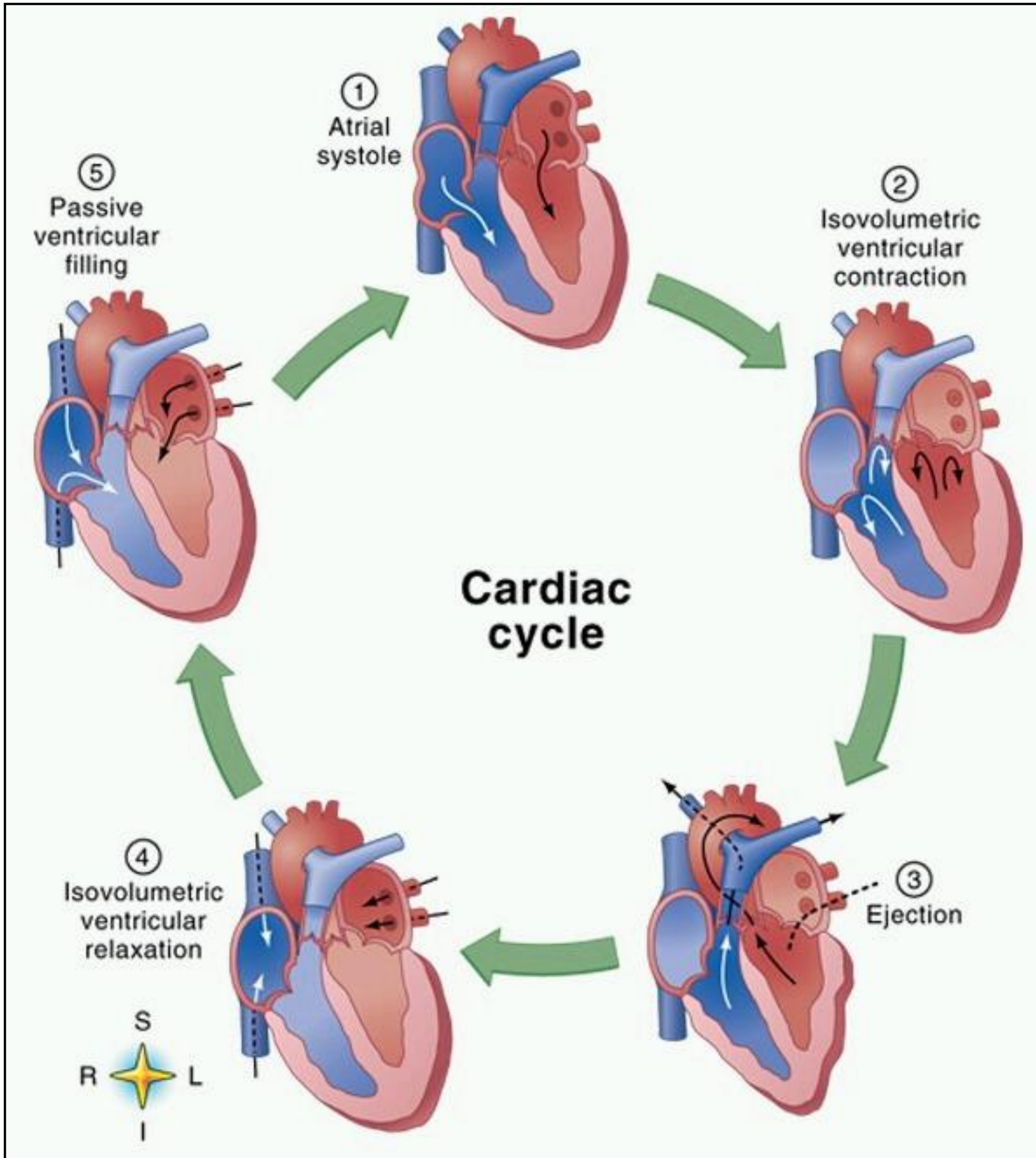
- Atria relax and begin refilling (atrial diastole)
- Ventricular diastole begins in this phase
- Identified by the closure of the SL valves and opening of the AV valves
  - Note pressure in the atria must exceed the ventricles for the valves to open
- Interventricular pressure decreases while volume stays the same
- Second heart sound heard
- Atrial diastole is 0.7 seconds
- Ventricular systole is 0.3 seconds



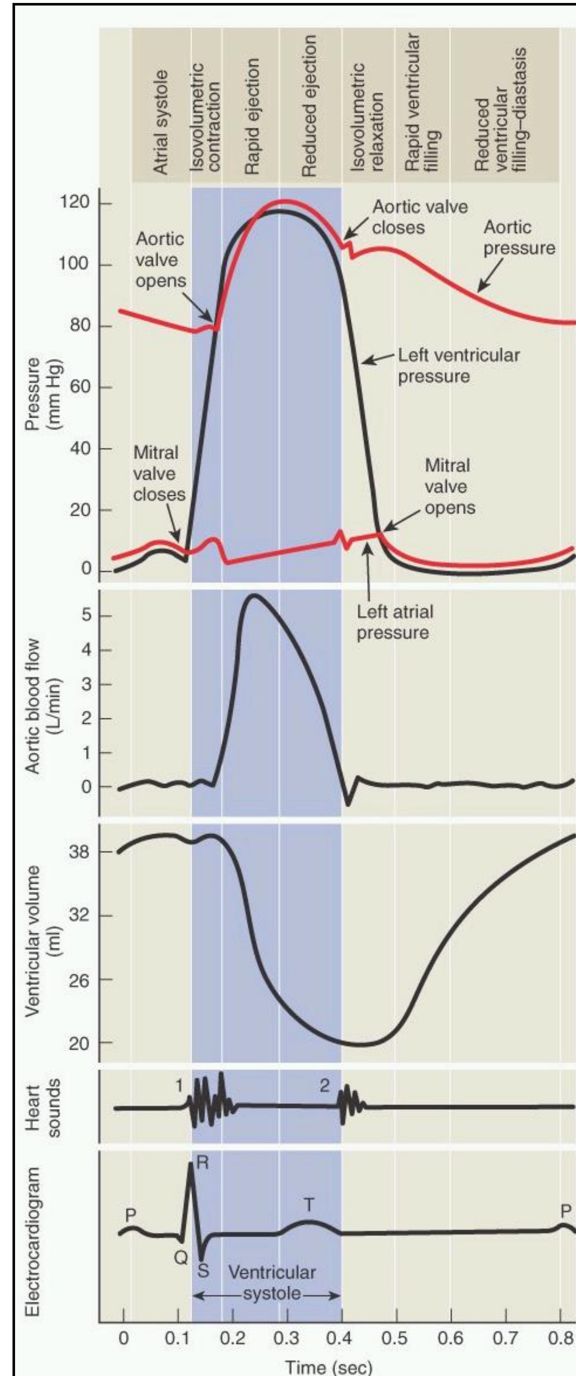
Passive Ventricular Filling

- Atria have been filling
- Interatrial volume and pressure have exceeded interventricular pressure
- Forces AV valves open
- Relaxation of the ventricles helps open AV valves with the help of papillary muscles and chordae tendineae
- Initial abrupt filling of the ventricles (0.1 seconds)
- Followed by a continuous flow (diastasis)
  - 0.2 seconds
  - Marked by an increase in ventricular volume and pressure
- Total ventricular diastole is 0.5 seconds





1 Atrial systole
2 Isovolumetric ventricular contraction
3 Ejection
4 Isovolumetric ventricular relaxation
5 Passive ventricular filling
Cardiac cycle
S
R
L
I



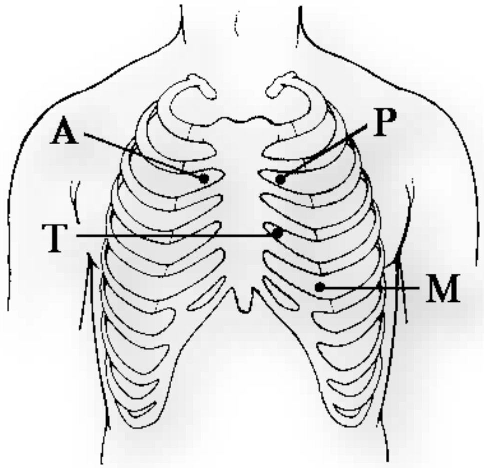
Atrial systole
Isovolumetric contraction
Rapid ejection
Reduced ejection
Isovolumetric relaxation
Rapid ventricular filling
Reduced ventricular filling–diastasis
Aortic valve opens
Aortic valve closes
Aortic pressure
Left ventricular pressure
Mitral valve closes
Mitral valve opens
Left atrial pressure
Pressure (mm Hg)
Aortic blood flow (L/min)
Ventricular volume (ml)
Heart sounds
Electrocardiogram
P
Q
R
S
T
Ventricular systole
Time (sec)

Heart Sounds

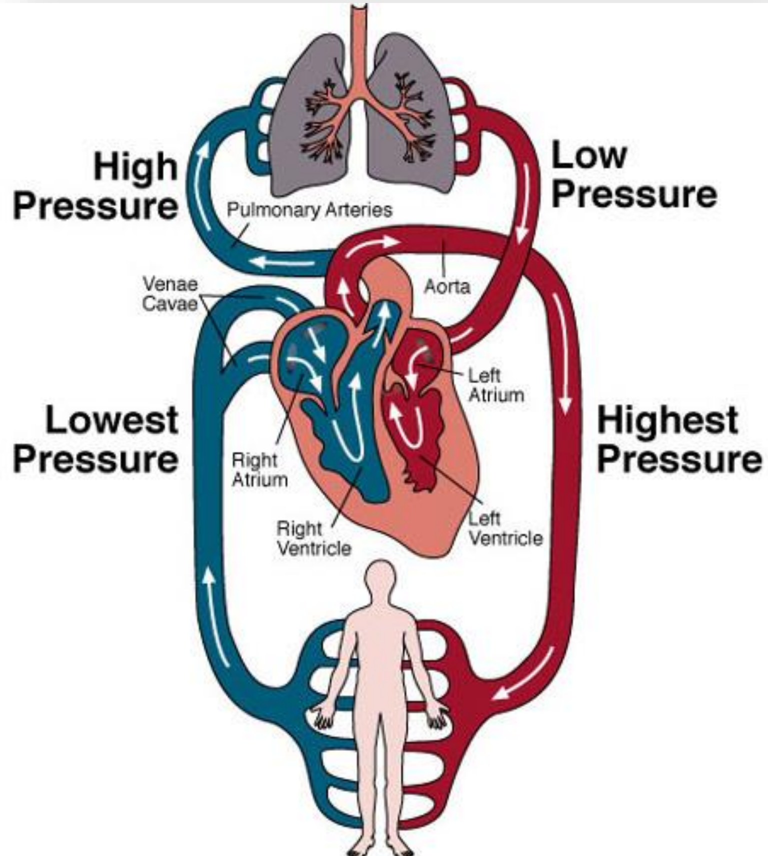
- Sounds made during the cardiac cycle
- Usually described as “lubb-dubb”
- First (S1)
  - Caused by contraction of the ventricles and closure of the AV valves
  - Longer and lower then second
- Second (S2)
  - Caused by closure of the SL valves
  - Shorter and sharper then the first

Heart Sounds

- Abnormalities in heart sounds may indicate problems with the functioning of the valves (difficult to hear if HR > 100)
  - S3 (ventricular gallop)
  - S4 (atrial gallop)
- For auscultation use landmarks in picture with patient in the supine position
  - A-Aortic
  - P-Pulmonic
  - T-Tricuspid
  - M-Mitral



Principles of circulation



- Fluid must move from an area of high pressure to an area of low pressure (down the pressure gradient)
  - Fluid will not move if the pressures are equal
  - Fluid moves from the left ventricle to the right atrium due to the blood pressure gradient

Mean Arterial Pressure

$$MAP = \frac{(2\ X\ DBP) + SBP}{3}$$

$$= \frac{(2\ X\ 80) + 120}{3}$$

$$= 93.3$$

$$MAP = DBP + \frac{Pulse\ Pressure}{3}$$

$$= 80 + \frac{(120\ - 80)}{3}$$

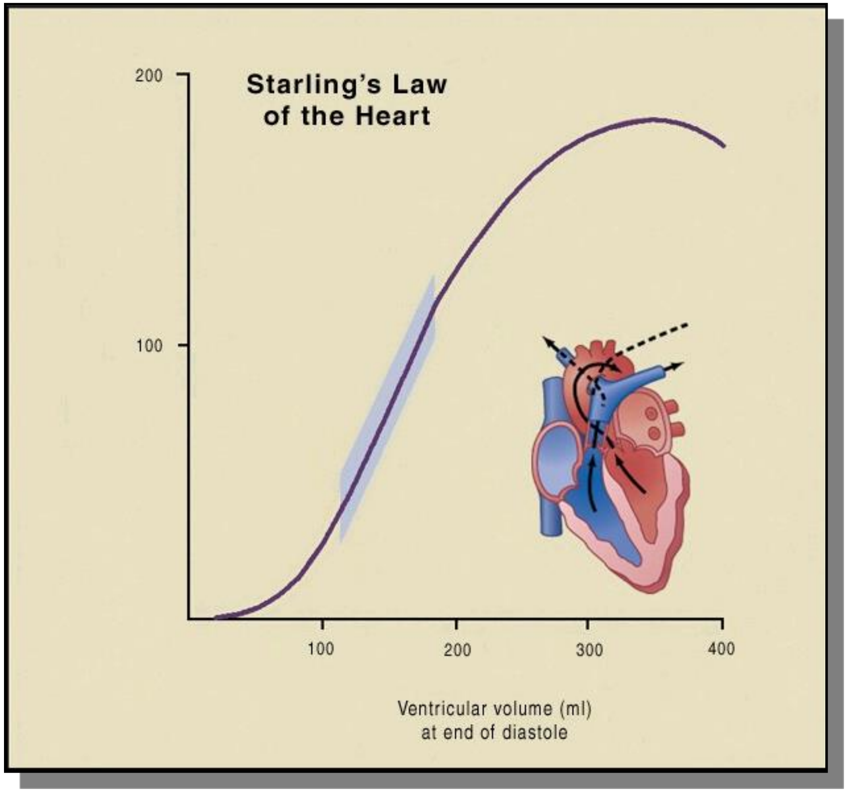
$$= 93.3$$

Stroke Volume

- The amount of systolic discharge (ml/beat)
- Factors that affect SV
  - Mechanical (Starling's Law of the Heart)
  - Neural
  - Chemical (inotropic effects of dopamine and epinephrine)

Starling's Law of the Heart

- Pertains to the length of the myocardial fibers at the beginning of the ventricular contraction
- The longer the stretch the stronger their contraction
- Related to the amount of blood in the ventricles at the end of the ventricular diastolic phase (LVEDV)
- Note:
  - Too much blood may extend the fibers past their critical point and cause them to loose their elasticity



Heart Rate

- The rate at which the heart beats (b/min)
- Influential Factors:
  - Ratio of sympathetic and parasympathetic impulse per minute
  - Parasympathetic
    - Vagus nerve
    - Inhibitory by releasing acetylcholine
  - Sympathetic
    - Cardiac nerve
    - Excitatory by releasing norepinephrine

Heart Rate

- Cardiac Pressoreflexes:
  - Baroreceptors in the carotid arteries and aorta sense changes in pressure
  - Carotid Sinus Reflex
    - Found at the base of the internal carotid
    - Baroreceptors attach to Herring's nerve (an extension of the glossopharyngeal (IX) cranial nerve) send signal to cardiac center in the medulla oblongata
    - If pressure is increased then vagus stimulation occurs slowing the HR down
  - Aortic Reflex
    - Found in the aortic arch
    - Through the aortic nerve into the vagus nerve (X) to the cardiac center
    - An increase in pressure will again stimulate a drop in HR

Heart Rate

- Other reflexes
  - Emotions
  - Exercise
  - Hormones
  - Temperature
  - Pain
    - Visceral structure stimulation may result in such a slowing of HR that fainting may occur

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Heart Rate

- Carotid Sinus Reflex:
  - Baroreceptors in the carotid arteries and aorta sense changes in pressure
  - Send impulse to cardiac center in the medulla
  - Oppose changes in pressure by adjusting the heart rate

Preload

- The amount of blood returning to the heart during the diastolic phase
  - During diastole blood flows from the atria to the vents
  - Volume of each ventricle (EDV) is approximately 120 – 130 ml
  - Vents empty during systole so volume decreases (ESV) – approximately 50 – 60 ml
  - Therefore
    - PL= EDV – ESV = 120 ml – 50 ml = 70 ml

Cardiac Output

- The amount of systolic discharge per minute (ml/min)

$$CO = HR\ X\ SV$$

$$= 72\ \frac{b}{min}\ X\ 70\ \frac{ml}{b}$$

$$= 5040\ \frac{ml}{min}$$

Blood Pressure

- BP = CO X PVR (peripheral vascular resistance)
- PVR
  - The resistance of blood flow by the force of friction between the blood and walls of the vessels
    - Viscosity of the blood
      - Changes in RBC volume or proteins
    - Diameter of the arterioles (over ½)
      - Decrease in diameter will limit the flow of blood and in turn leave larger amounts of blood in the arteries thus increasing the PVR

PVR

- Vasomotor Control Mechanism
  - Changes in blood distribution and/or pressure may stimulate the vasomotor center
  - When stimulated it sends sympathetic impulses to the muscles surrounding the vessels (venules, arterioles and the blood reservoir) to constrict

PVR

- Vasomotor Pressoreflexes
  - Increase
    - Stimulates baroreceptors (carotid and aortic)
    - Stimulates the cardiac center
    - Results in parasympathetic stimulation of the heart and inhibition of the vasoconstrictor center
    - ↓ HR and venous pooling
  - Decrease
    - Baroreceptors stimulate cardiac center
    - Sympathetic response to the vasoconstrictor center

PVR

- Vasomotor Chemoreflexes
  - – Found in the aorta and carotid bodies
  - – Sensitive to hypercarbia
    - Less sensitive to hypoxia
  - – Decreased arterial pH
  - – Stimulation causes the vasoconstrictor center to be activated

PVR

- Medullary Ischemic Reflex
  - This mechanism recognizes a large drop in the cerebral blood flow
  - This drop in BP causes ischemia to the medulla (resulting in hypercapnia)
  - Triggers an autonomic response of the cardiac and vasomotor centers of the medulla
  - This response causes sympathetic response to the heart and vessels (causing ↑ HR, ↑ force of contraction, vasoconstriction)
  - Also note that if the oxygen supply decreases to a very low point this mechanism can not be stimulated

PVR

- Vasomotor Control by Higher Brain Centers
  - Cerebral cortex and hypothalamus are capable of stimulating the vasomotor center
  - Seen with fear, anger and other emotions

Afterload

- Result of PVR
- ↑ PVR = ↓ SV
  - Due to ↑ aortic pressure and the ventricles now must overcome this pressure first
- ↓ PVR = ↑ SV
  - If sufficient enough volume is present

Terminology

- Chronotropy
  - Refers to heart rate
- Inotropy
  - Refers to contractile strength
- Dromotropy
  - Refers to rate of nerve impulse conduction

Venous Return

- The amount of blood returned to the heart
- Affect by
  - Venous pumps
  - Total blood volume