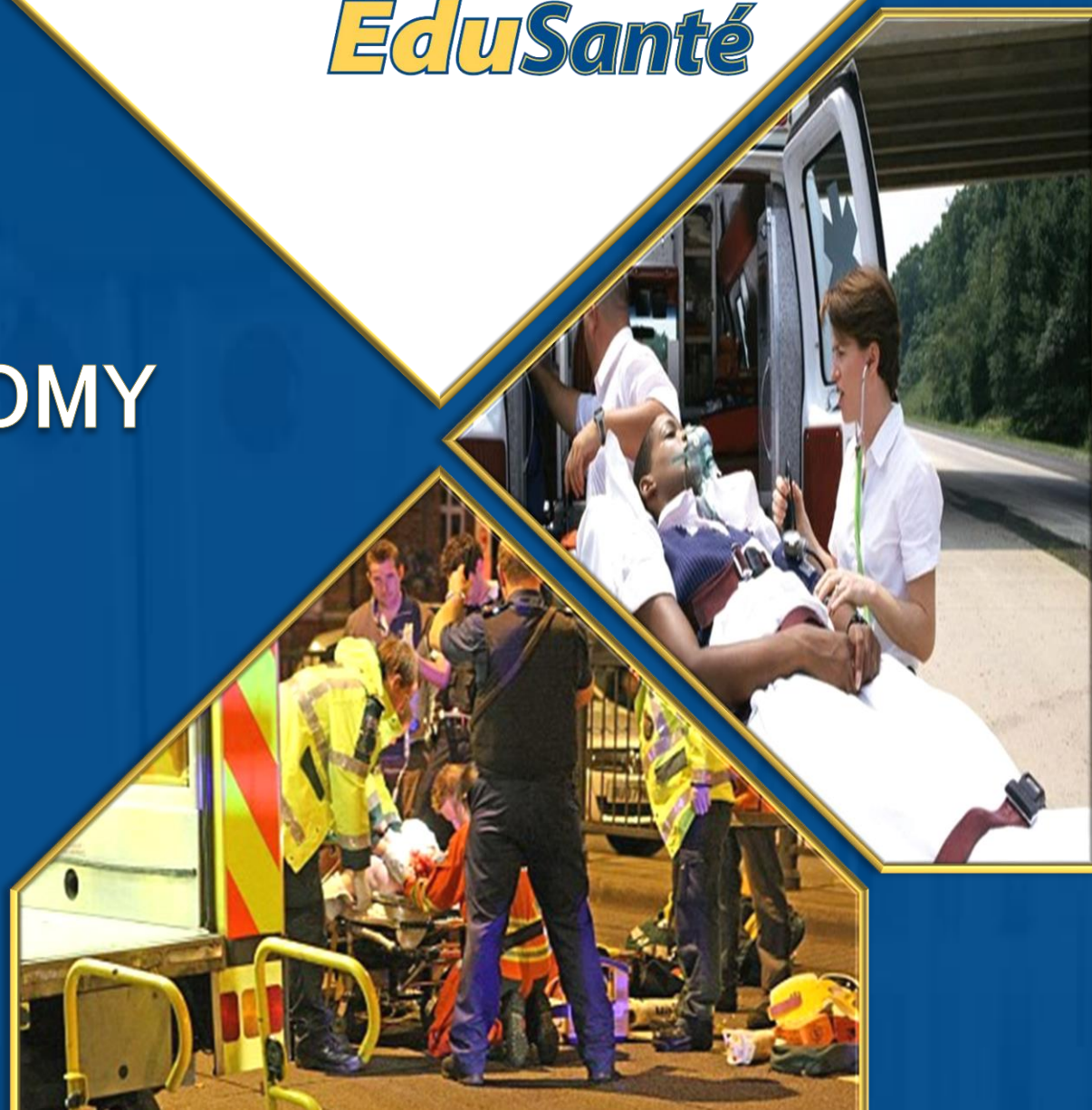
MEDAVIE HealthEd ÉduSanté

Cardiovascular Anatomy

Primary Care Paramedicine

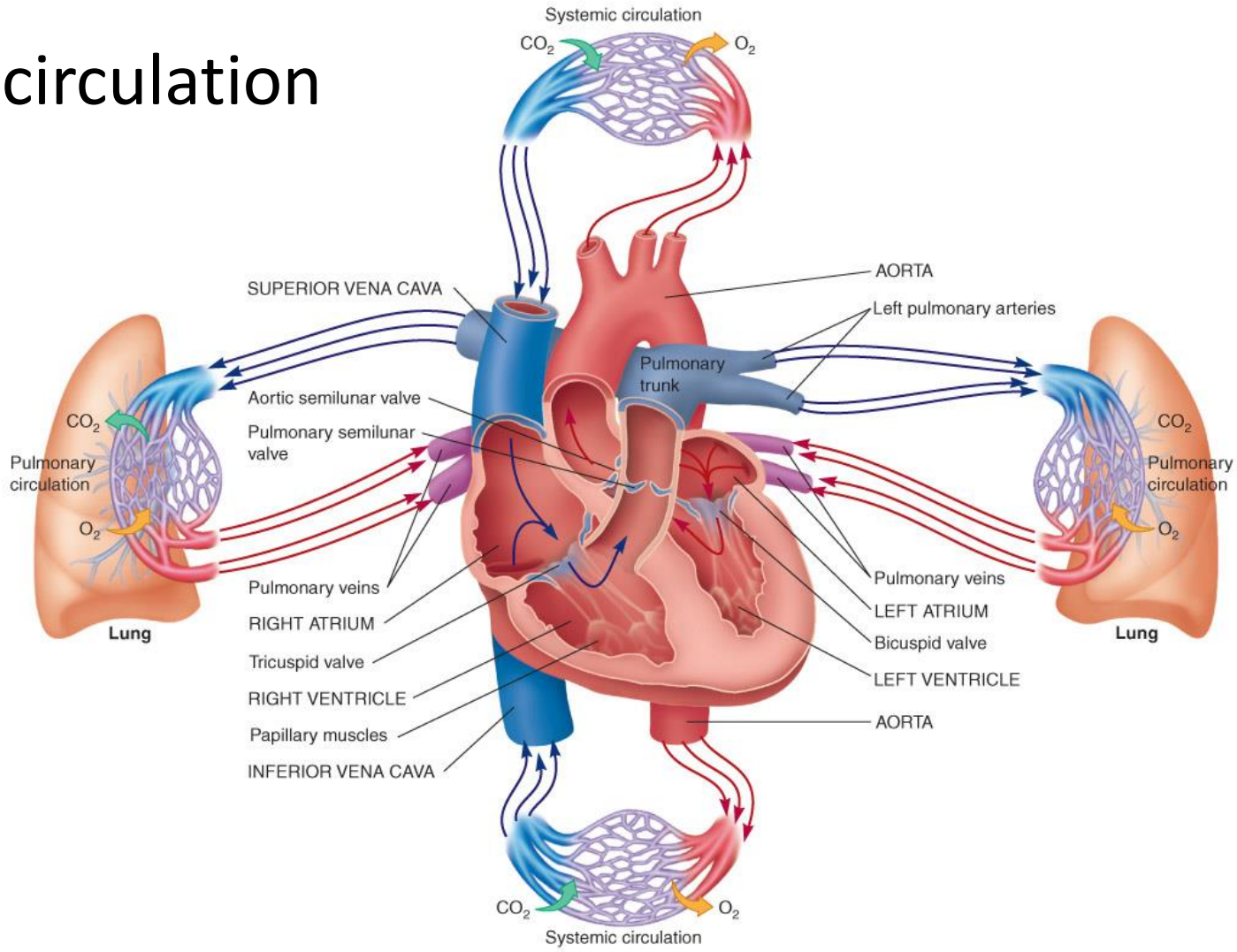


Module: 12

Section: 02

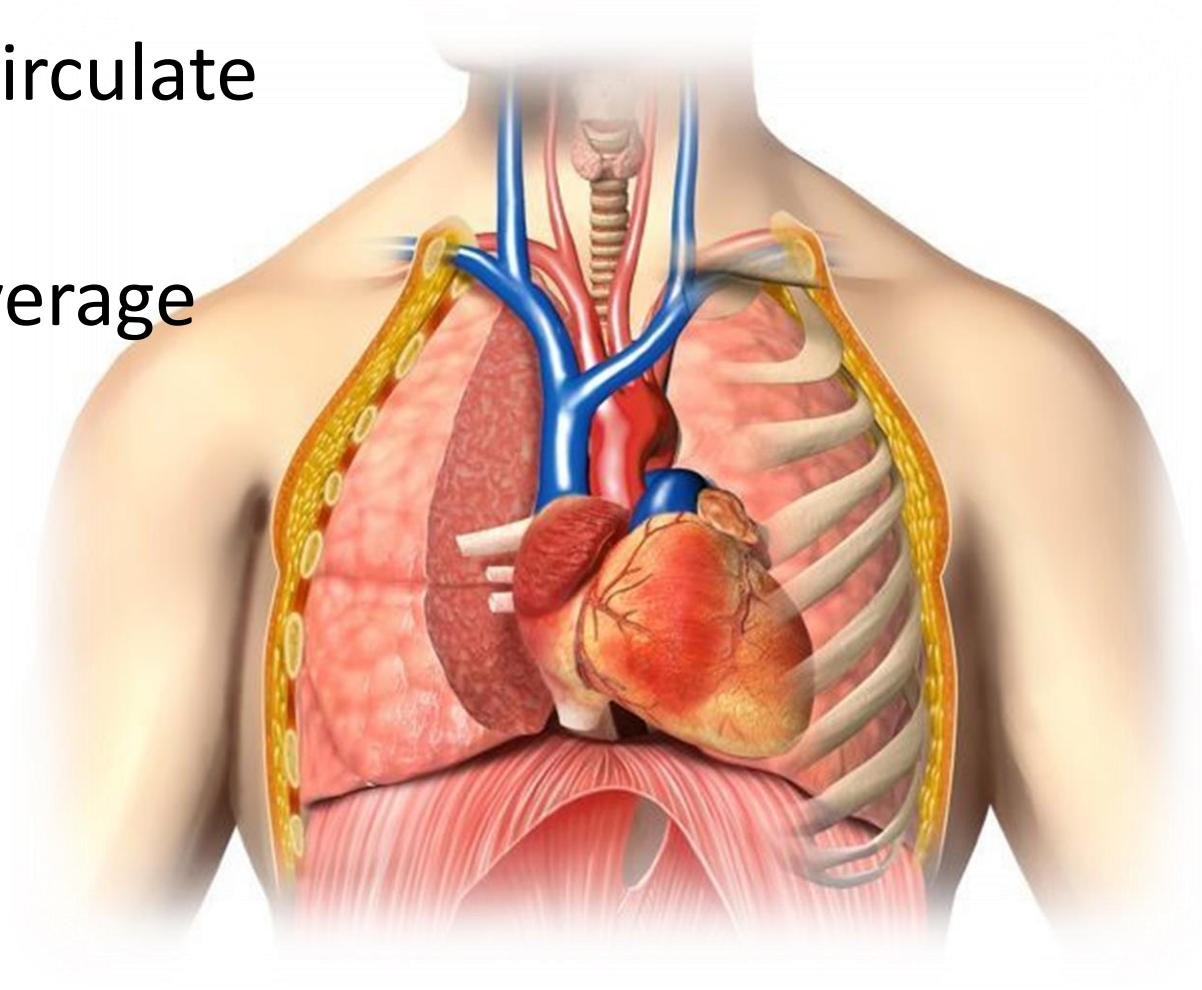
The Cardiovascular System

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



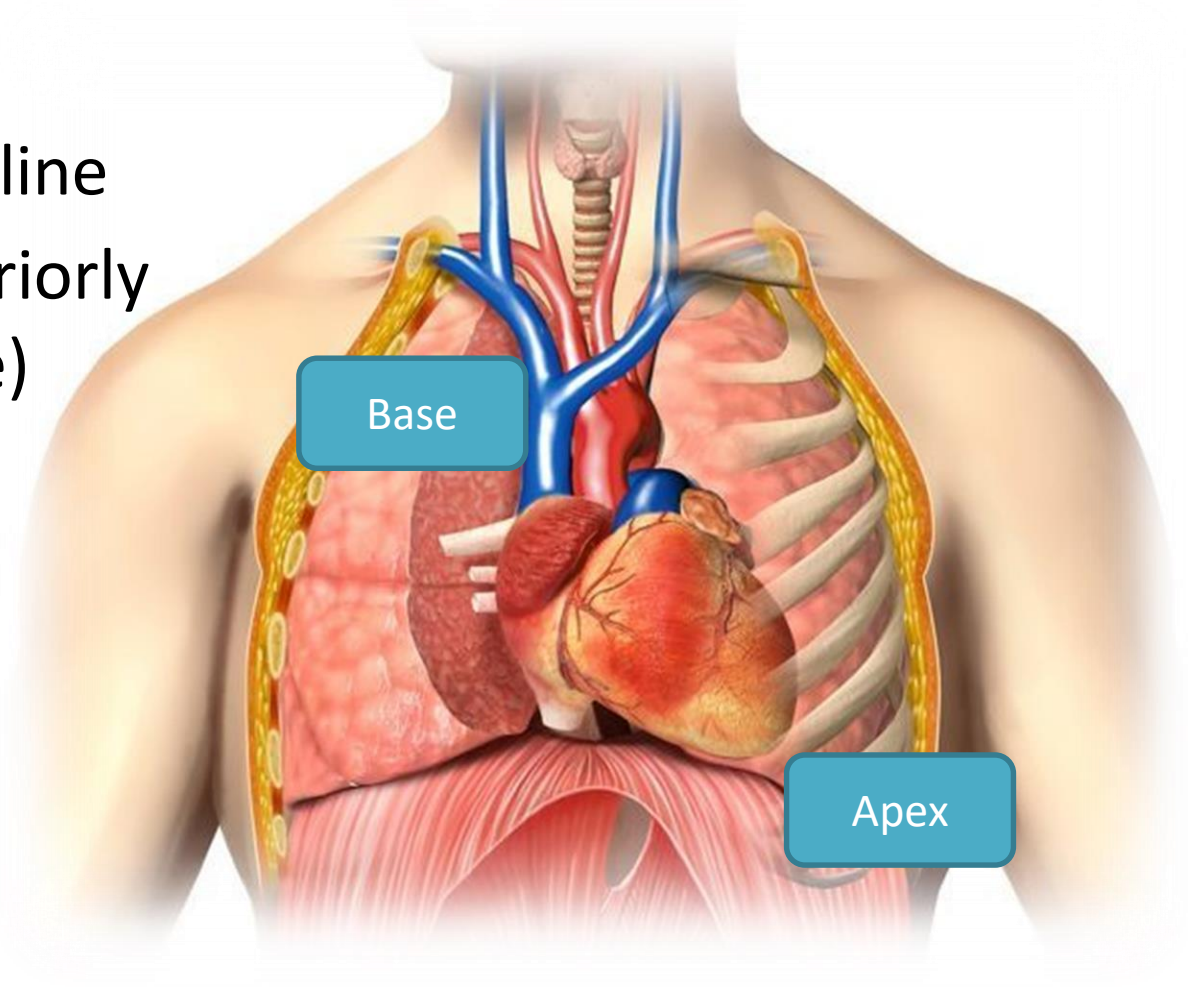
The Heart

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



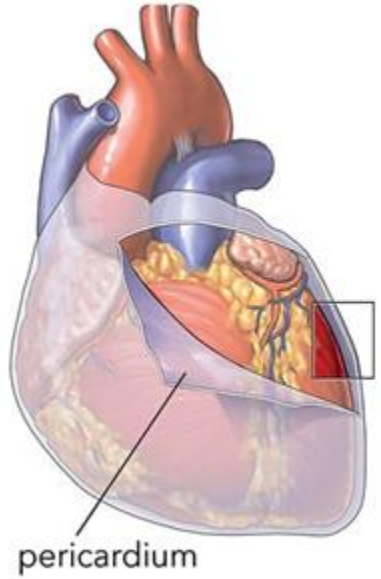
The Heart

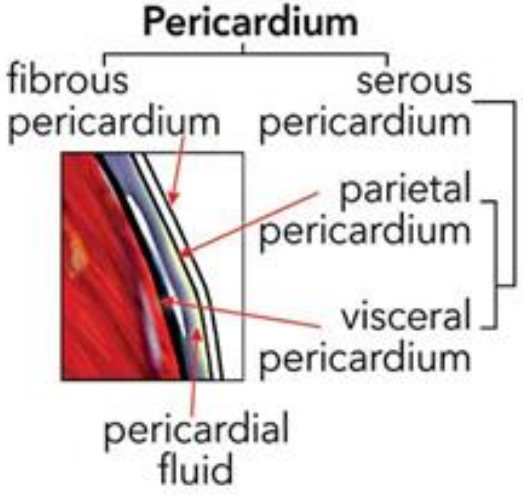
- Located in the mediastinum:
  - Posterior to the sternum
  - Rests on diaphragm, 2/3 left of midline
  - The apex is directed inferiorly, anteriorly and to the left (5th intercostal space)
  - The base has several large vessels attached and extends to the 2nd intercostal space
  - On average 9 - 12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



Pericardium

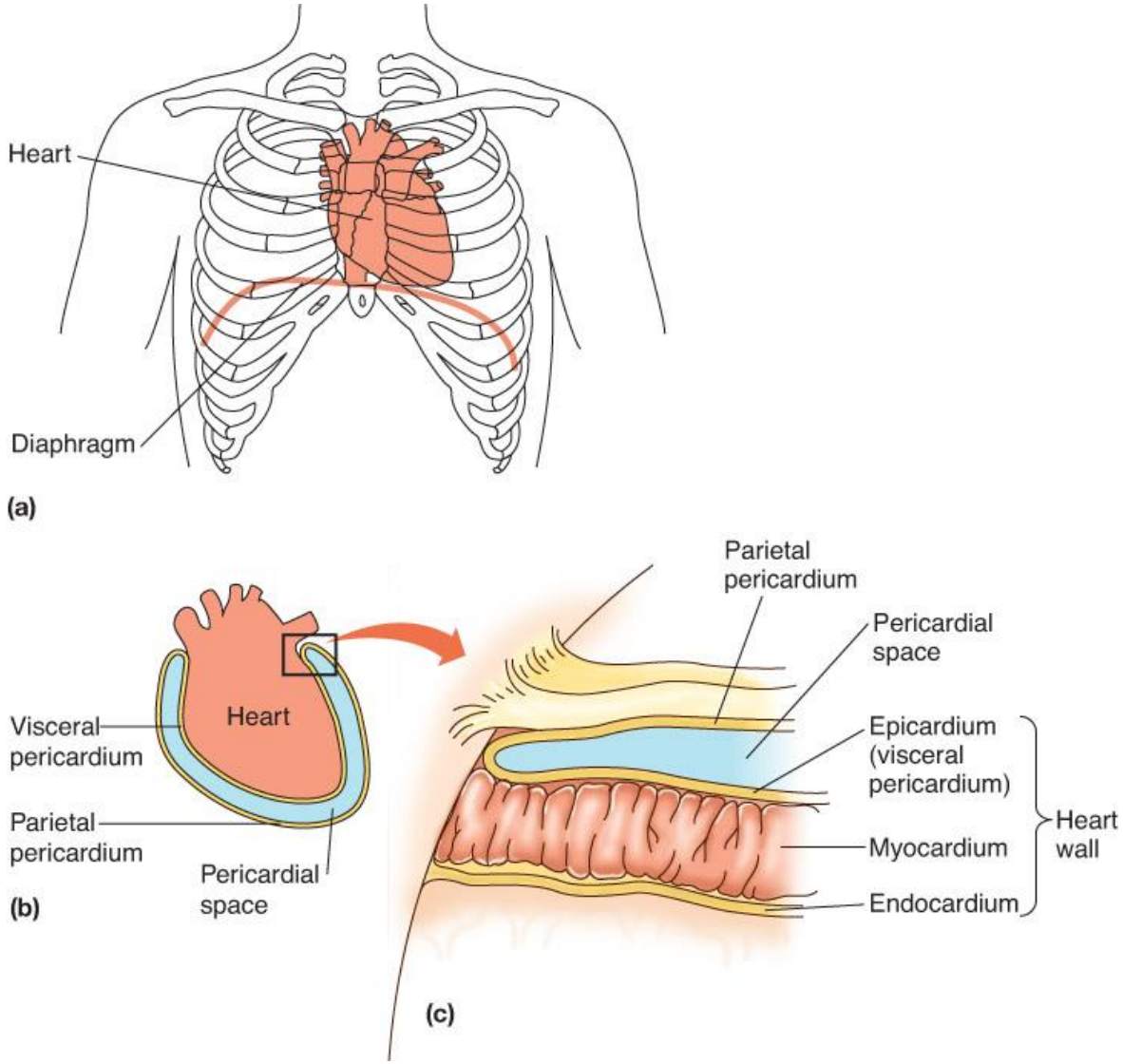
- 2 layer sac that covers the heart
  - Fibrous pericardium
    - Outer layer formed of tough white fibrous connective tissue
    - Attached to the large vessels at the base of the heart, diaphragm, sternum and vertebrae
  - Serous pericardium
    - Fibrous layer lined with serous membrane called parietal 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

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
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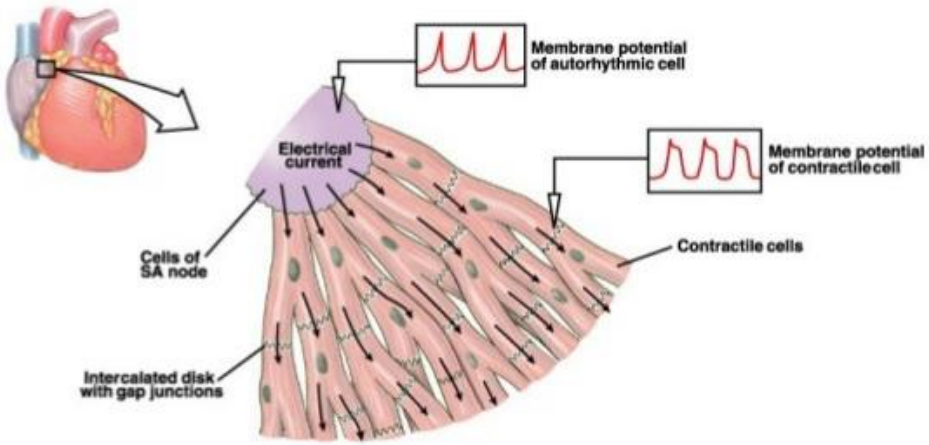
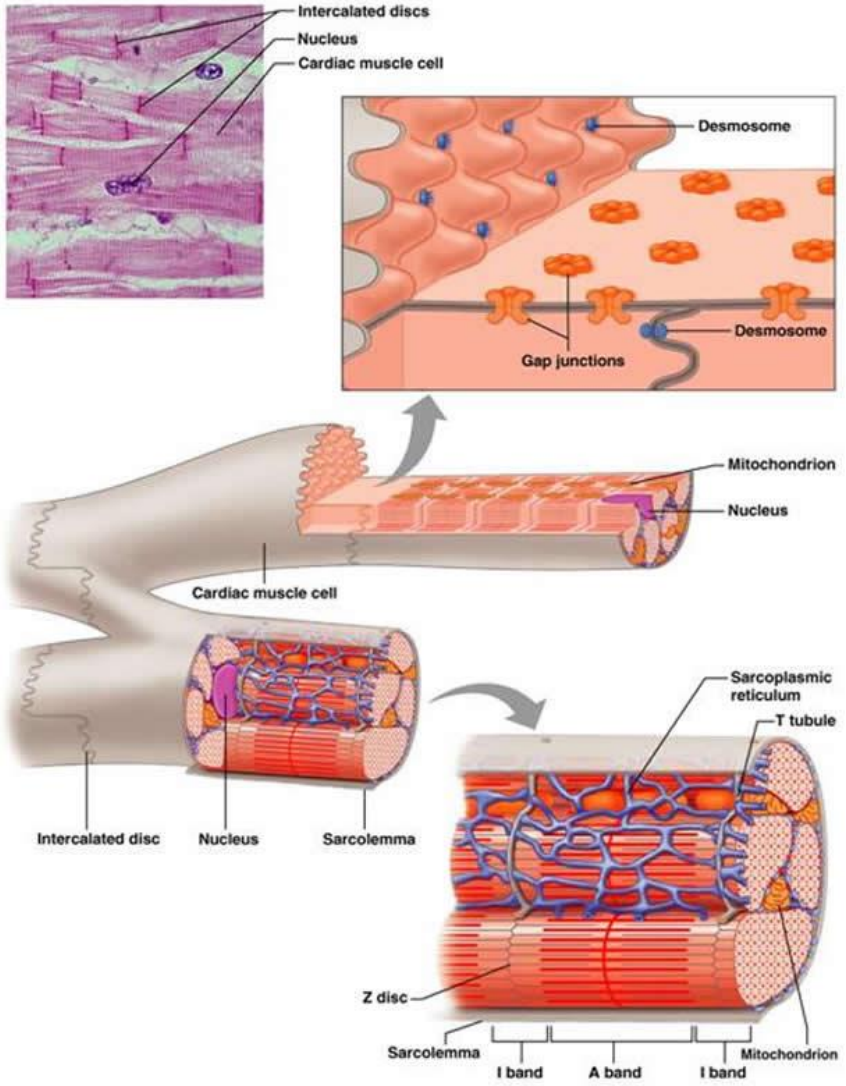
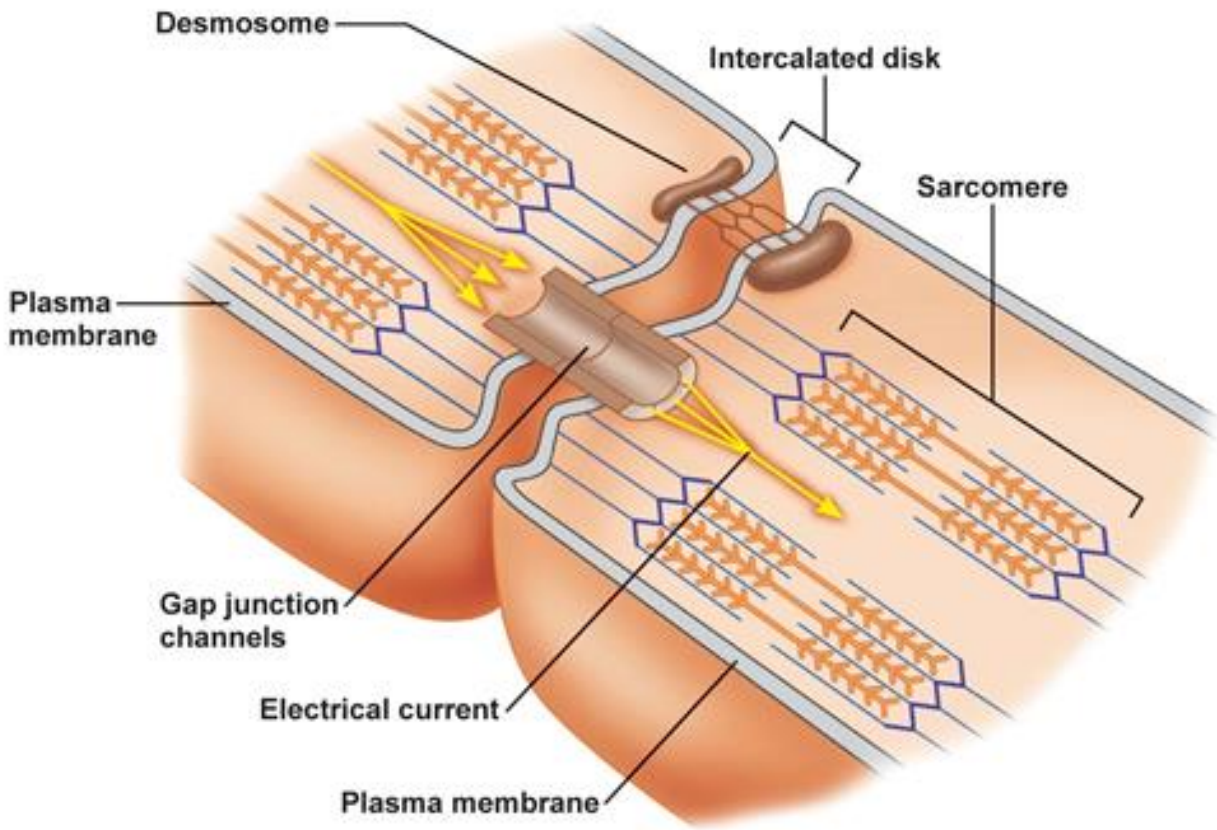


Myocardium

- 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

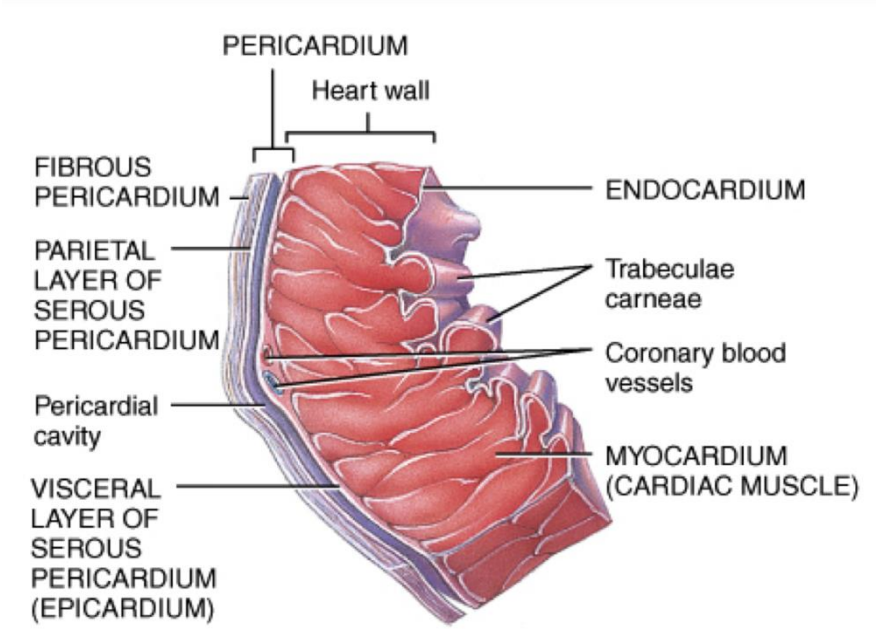
Intercalated Discs





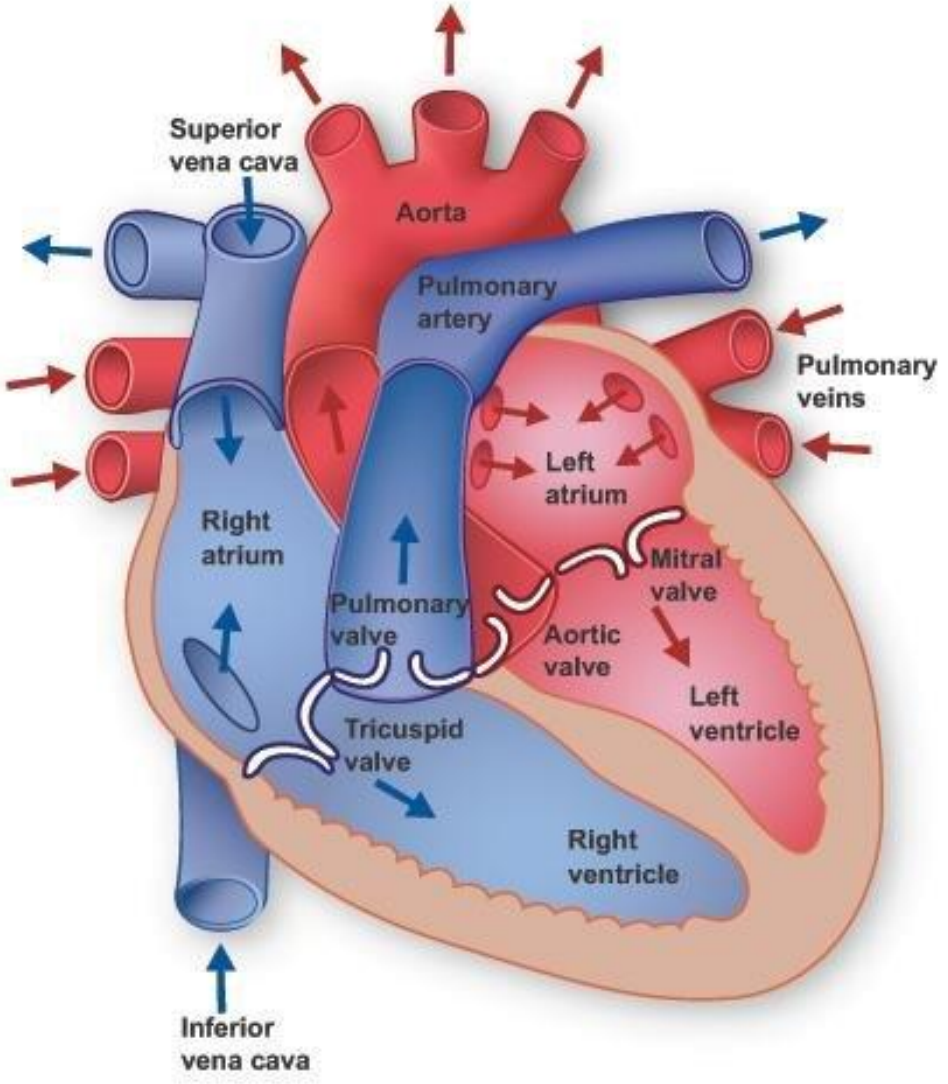
Endocardium

- 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

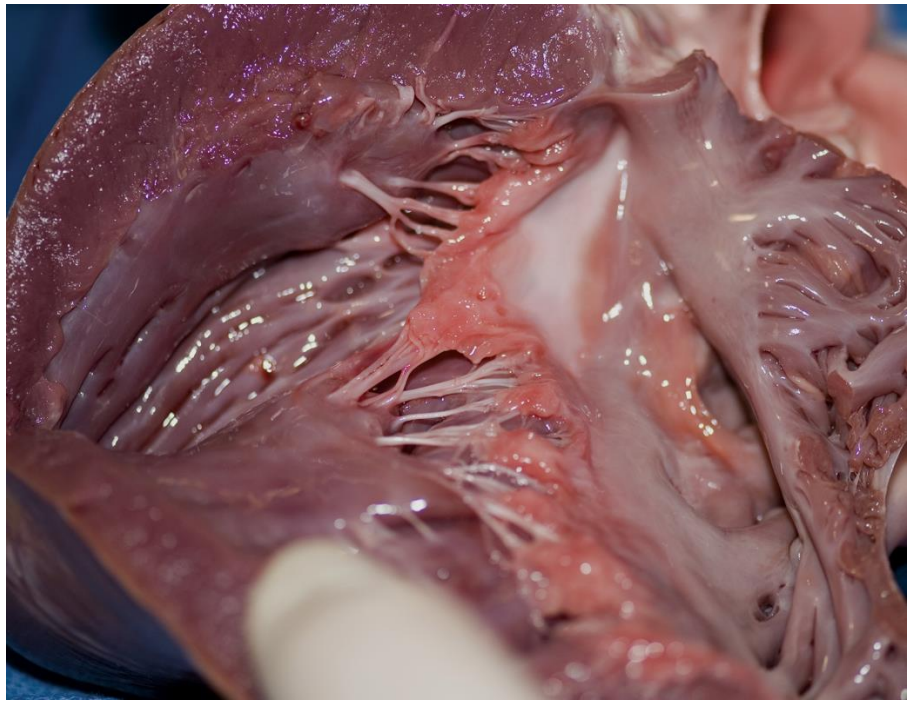
Ventricles

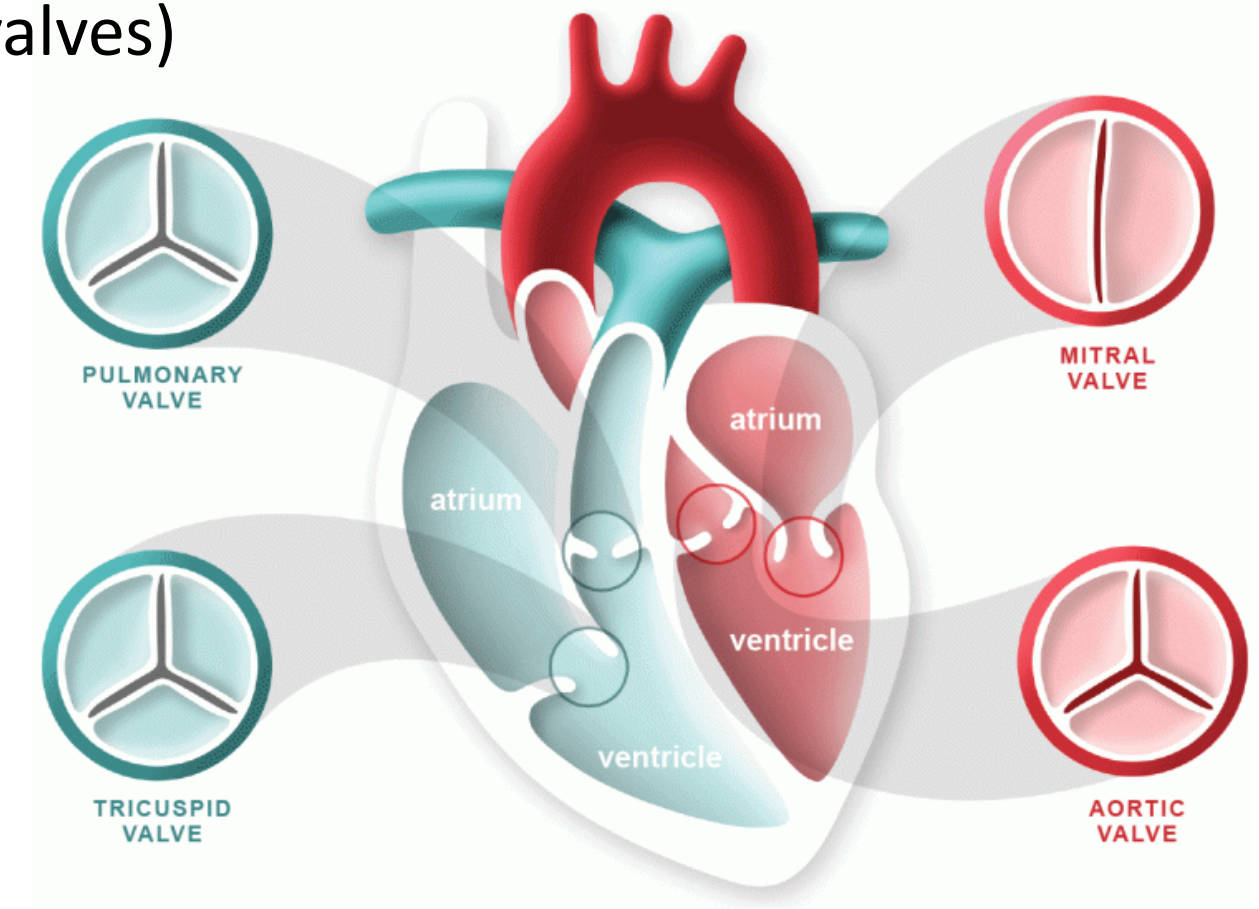
- Receives blood from the atria above
- Thicker myocardial layers (left is thickest)
- Are divided by interventricular septum
- Also have papillary muscles projecting from the wall

- 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

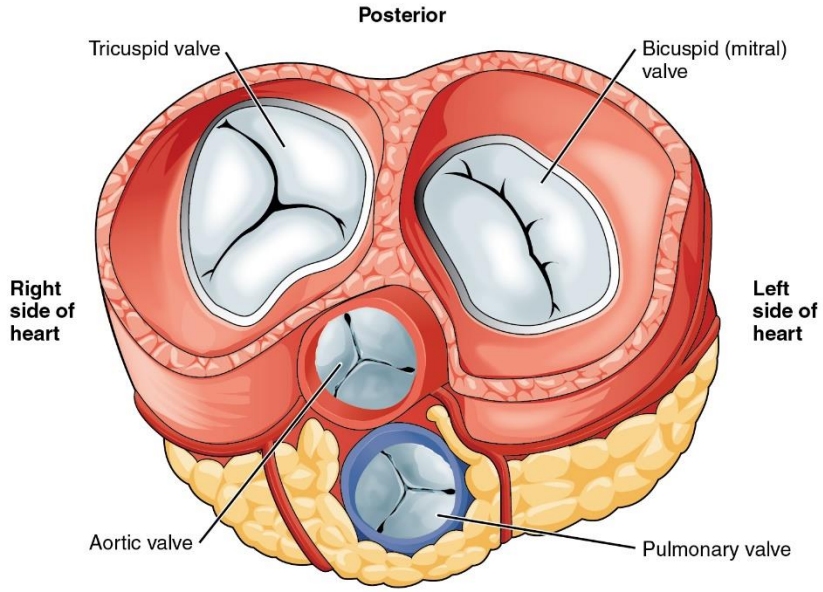
- Mechanical devices that permit the flow of blood
  - Atrioventricular valves (cuspid valves)
  - Semilunar valves

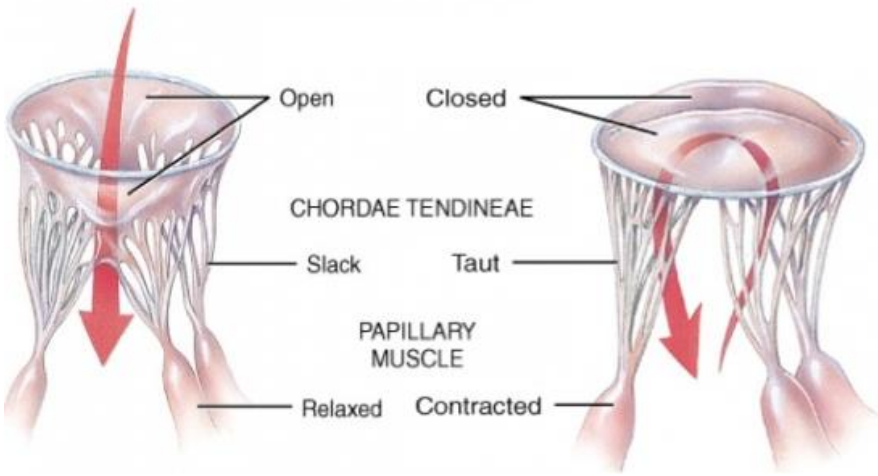




Atrioventricular Valves

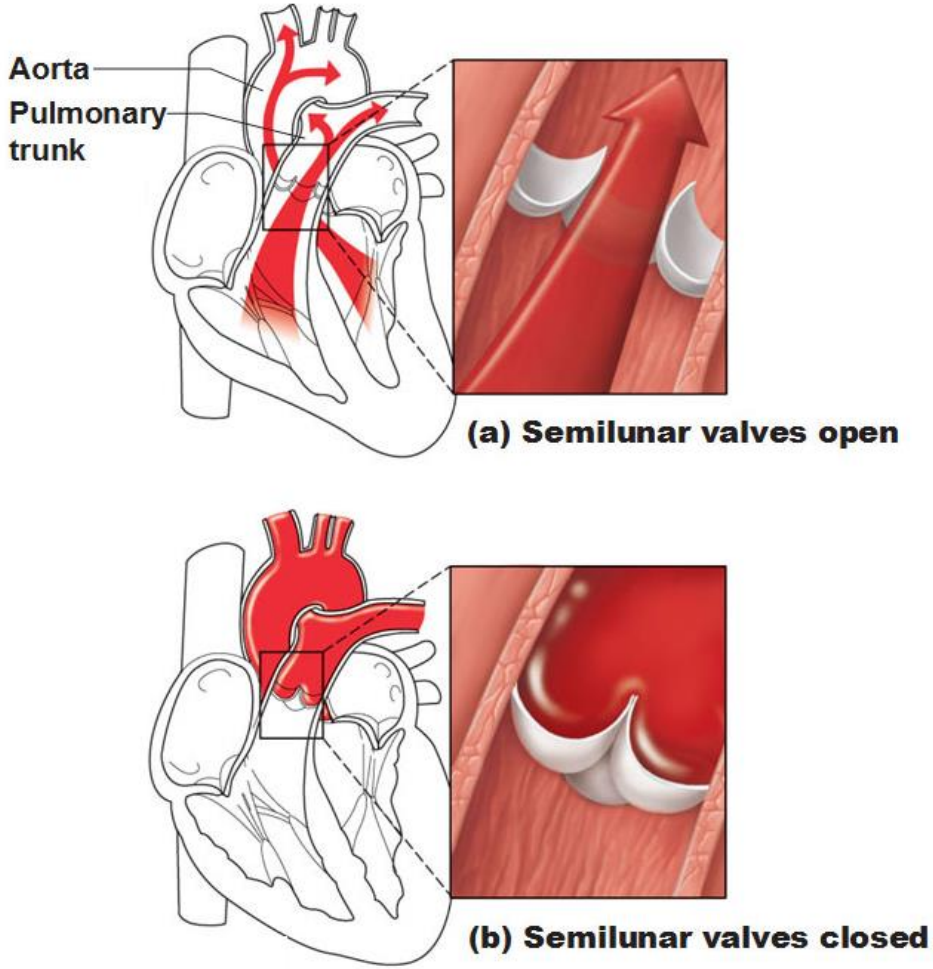
- Between the atrium and the ventricles
  - Tricuspid valve (right)
  - Bicuspid (mitral) valve (left)
- Free edges are attached to papillary muscles by chordae tendineae
- Forced open as blood returns to atria, and closed when the ventricles contract





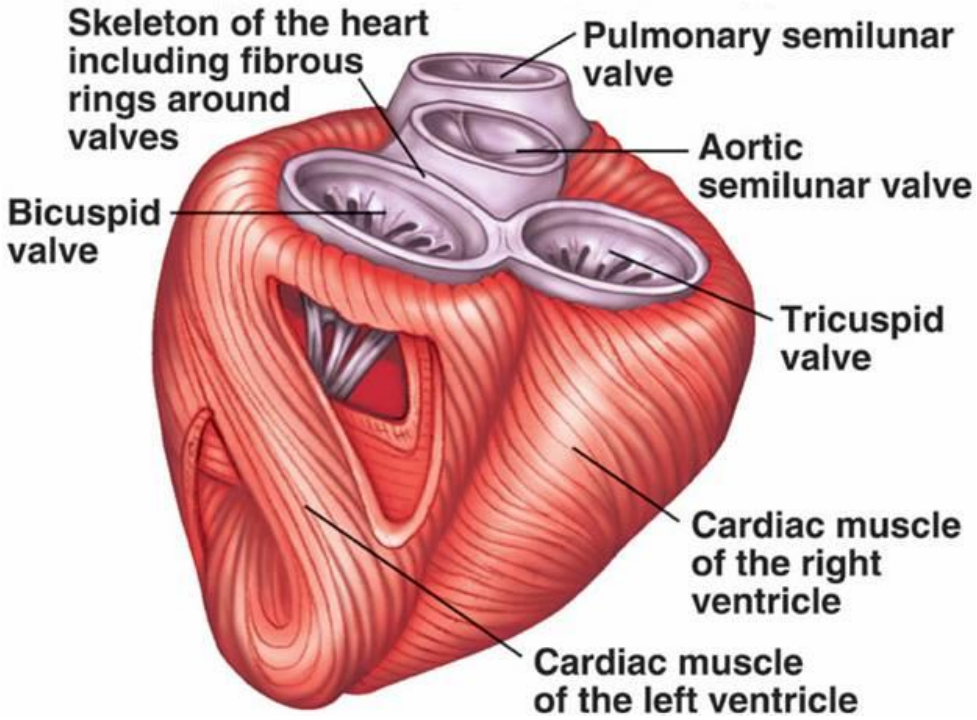
Semilunar Valves

- 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”



Skeleton

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



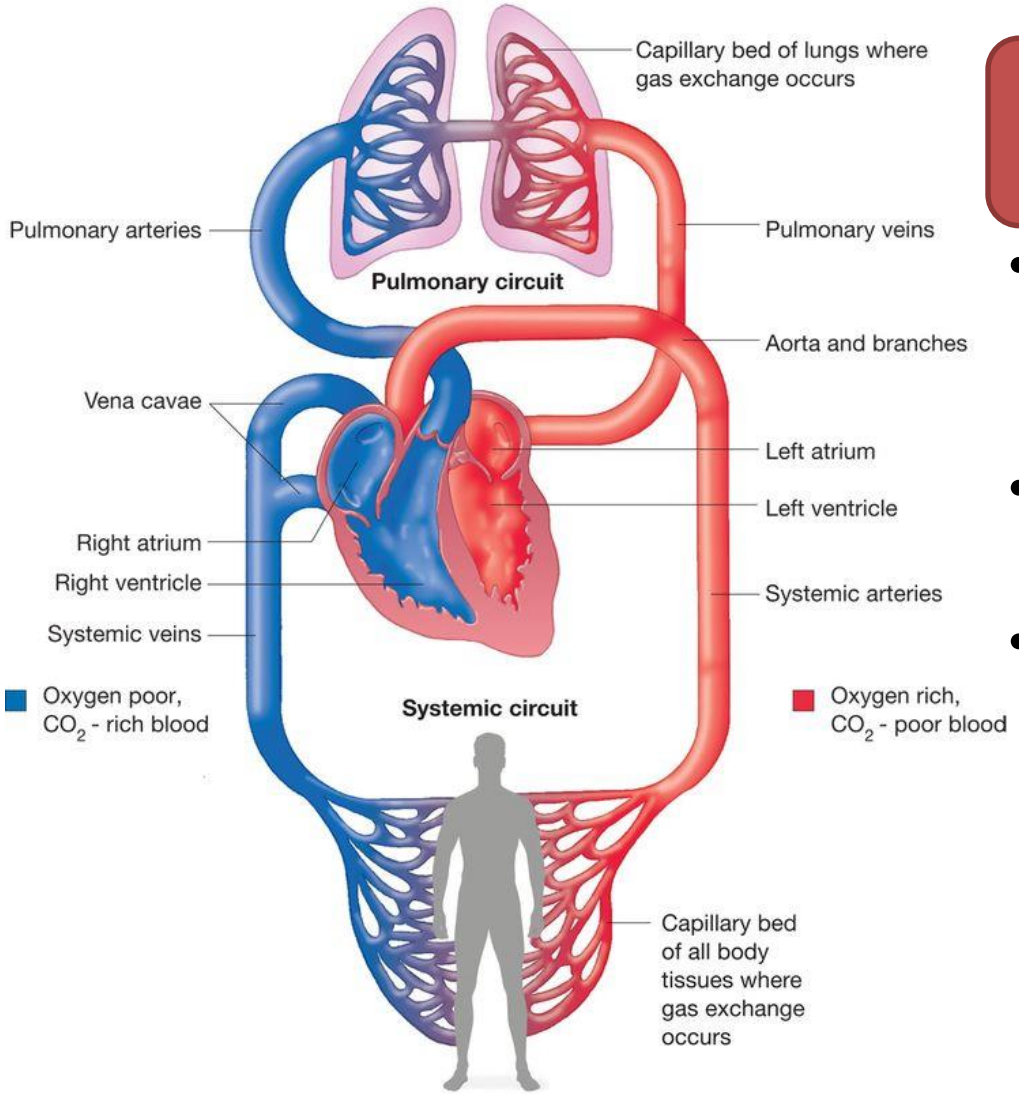
Flow of Blood

- 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

Pulmonary Circulation
(Right Pump)

- 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



Systemic Circulation
(Left Pump)

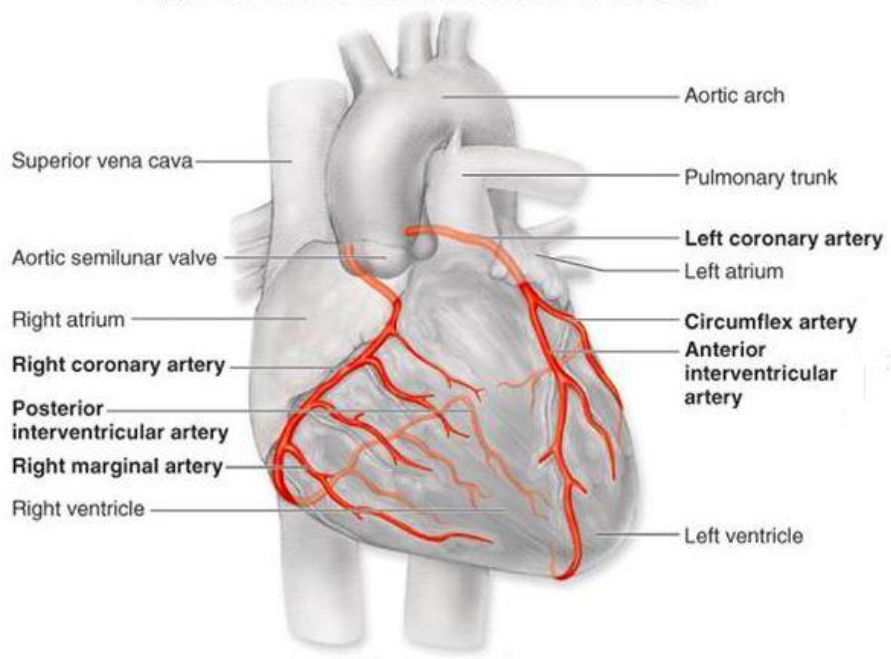
- Returns from lungs through pulmonary veins into LA
- Passes Mitral valve into the LV
- Passes the aortic SL valve into the ascending aorta to the body

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

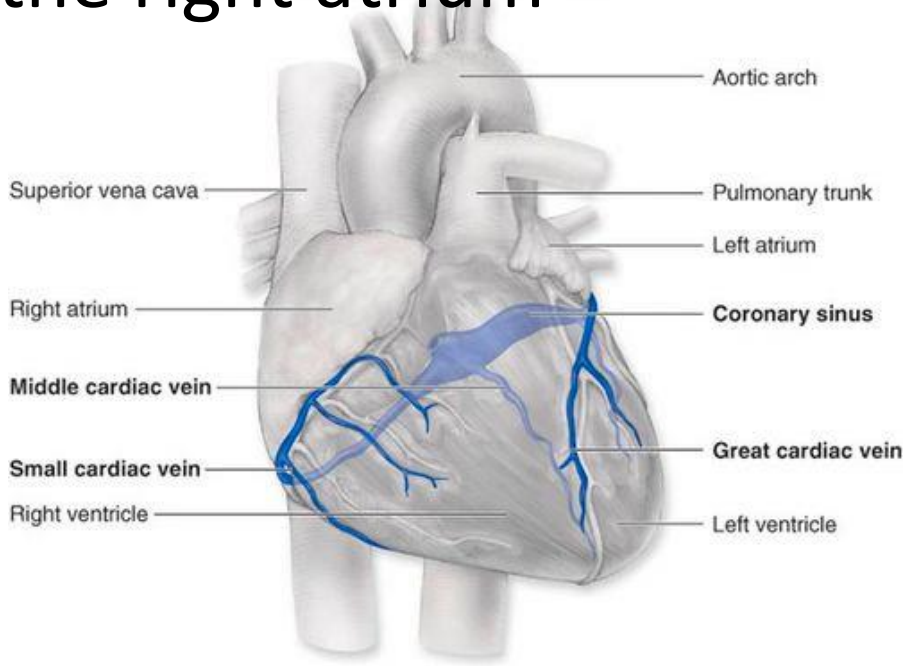
- Both ventricles receive blood from branches of the Rt and Lt coronary arteries
- Atrium receive blood from corresponding artery
- Coronary artery dominance

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

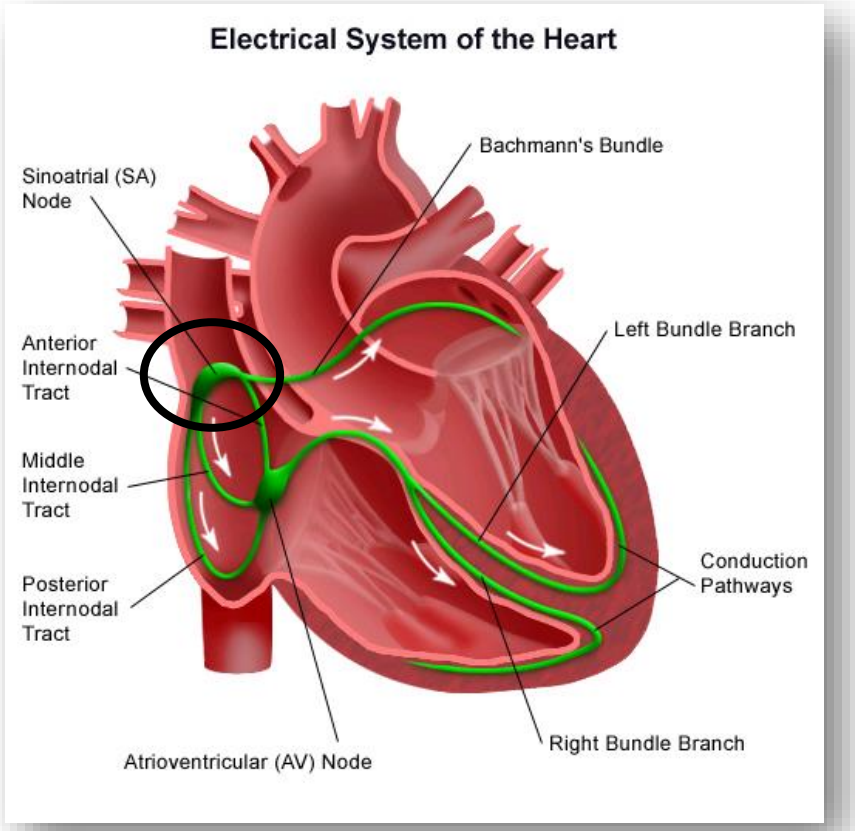
- Composed of
  - Sinoatrial node
  - Atrioventricular node
  - Atrioventricular bundle
  - Purkinje fibers
- Specialized cardiac cells
  - Differ in function where they conduct as well as of conduct for contraction

Table 30-4 Pacemaker Intrinsic Rates

Pacemaker	Rate (beats/min)
SA node	60 to 100
AV junction	40 to 60
Purkinje fibres	20 to 40

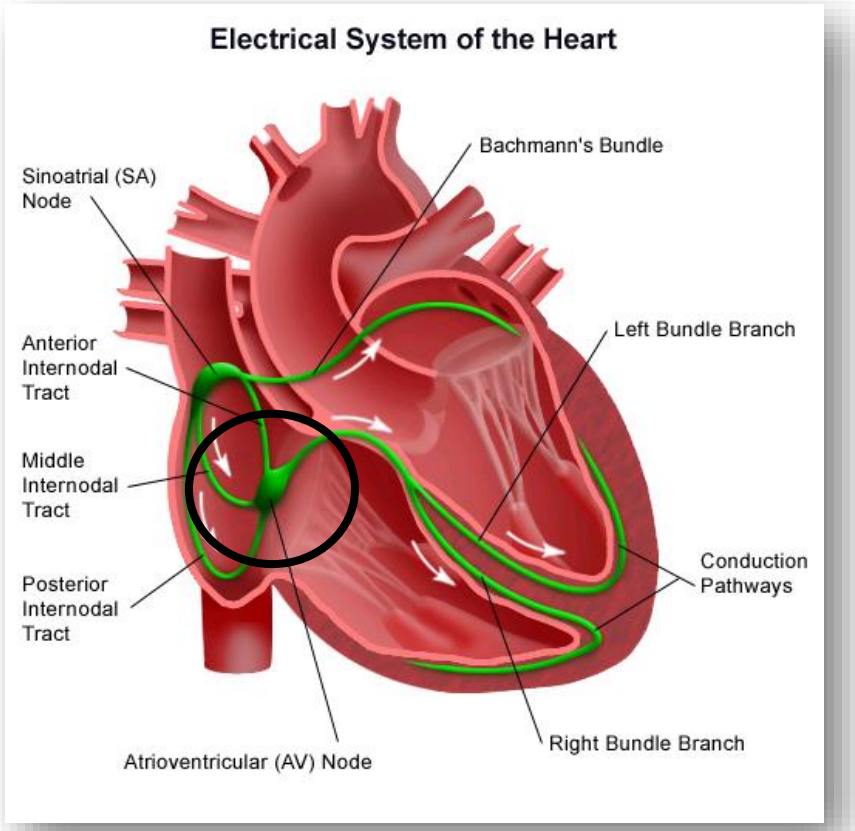
Abbreviations: AV, atrioventricular; SA, sinoatrial.

SA Node



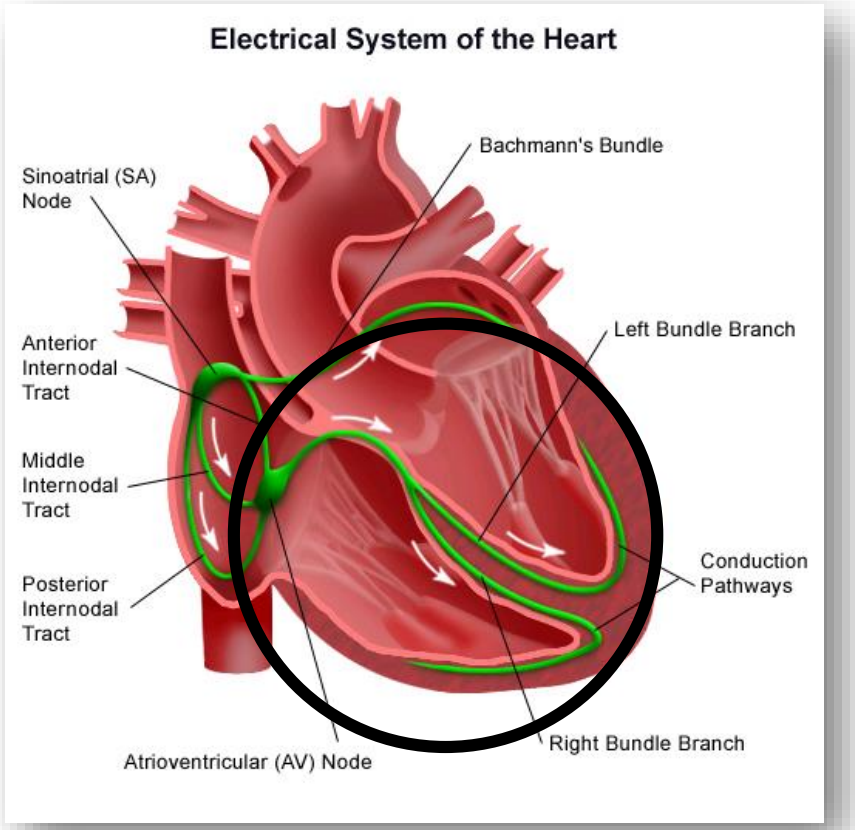
- Consists of hundreds of cells near the opening of the Superior VC
- Intrinsic rate of 60 - 100 bpm
- Establishes basic rhythm, known as the pacemaker
- Impulses rapidly transfer to the atrium and cause them to contract and to the AV Node

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

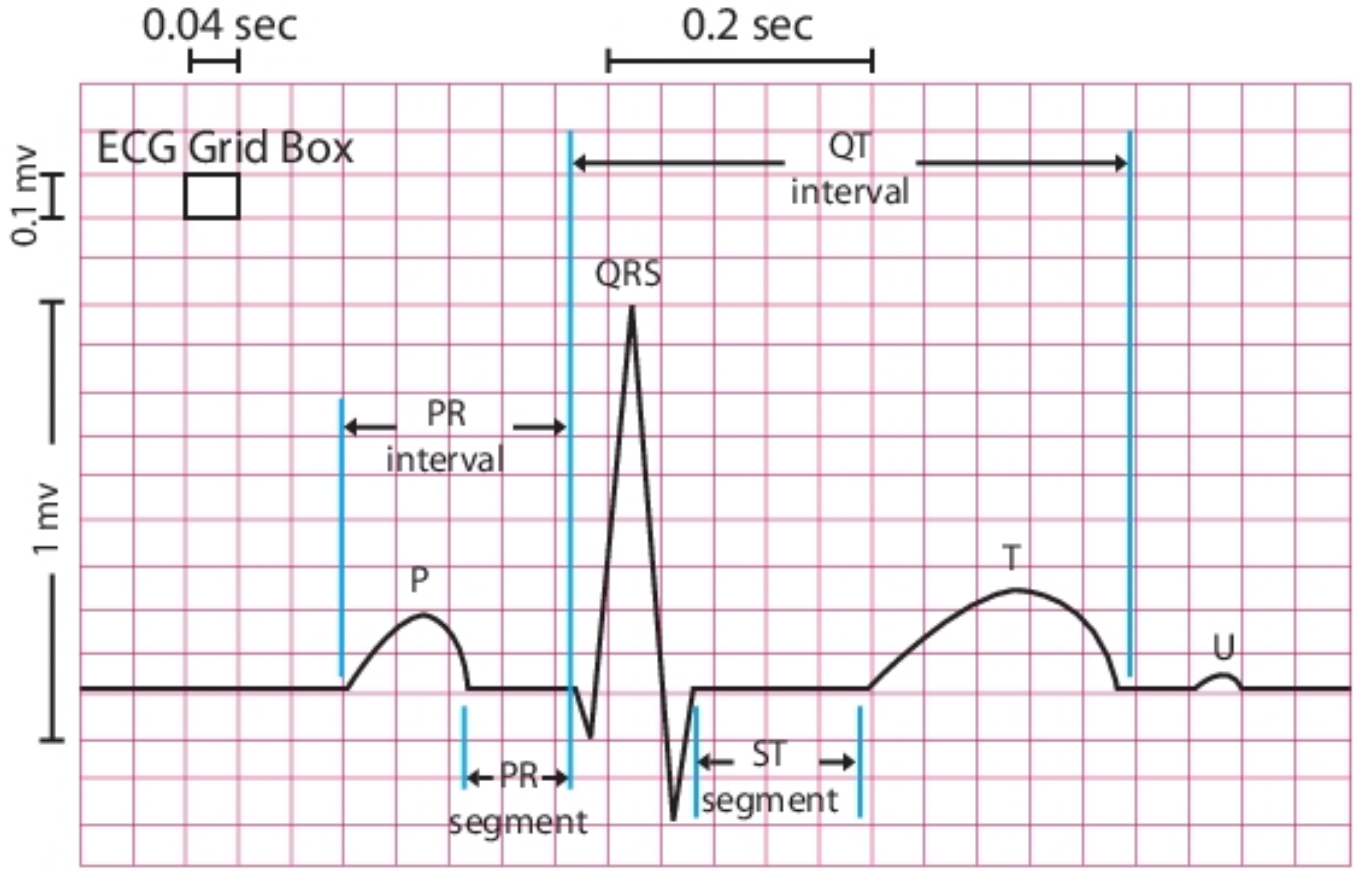
AV Bundle and Purkinje Fibers



- 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)

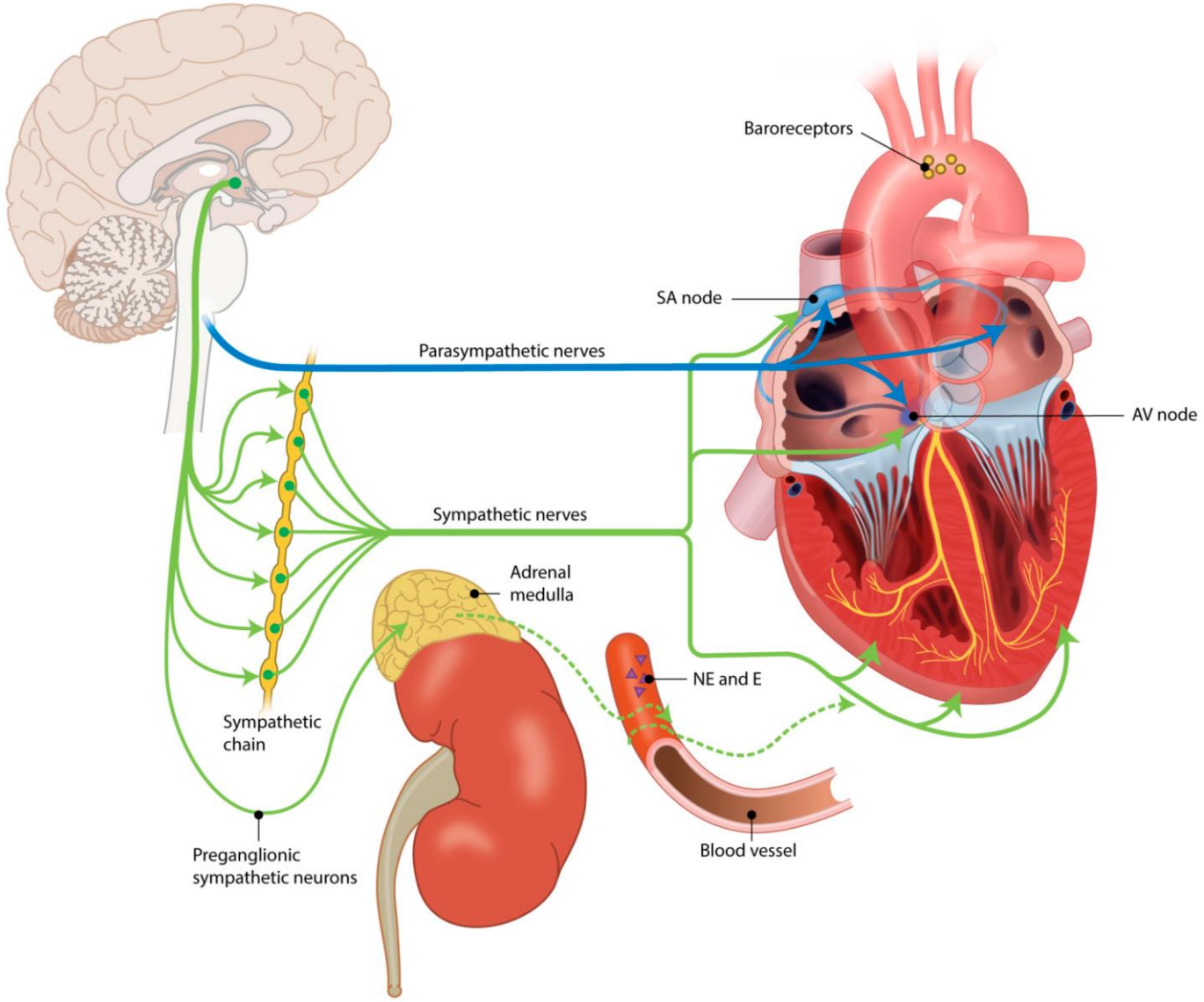
The ECG

- 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
- Terminate in the
  - SA node
  - AV node
  - Myocardium

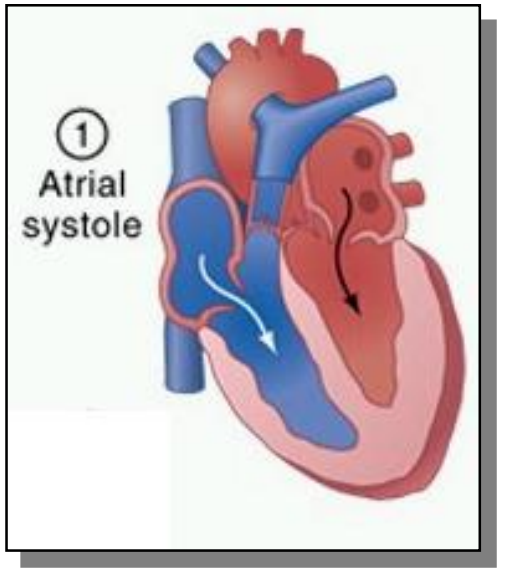


Cardiac Cycle

- 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

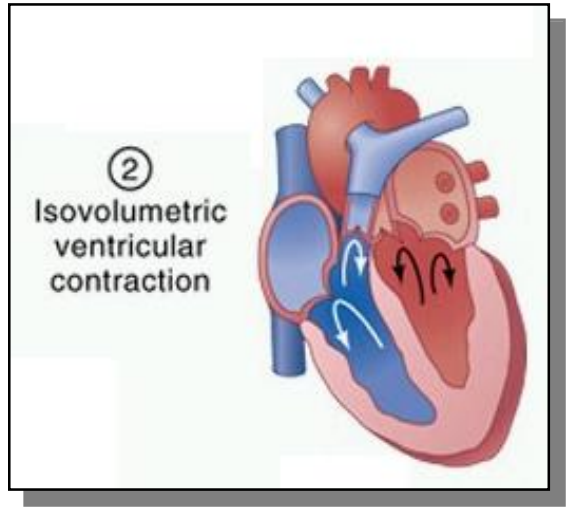
Atrial Systole

- 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



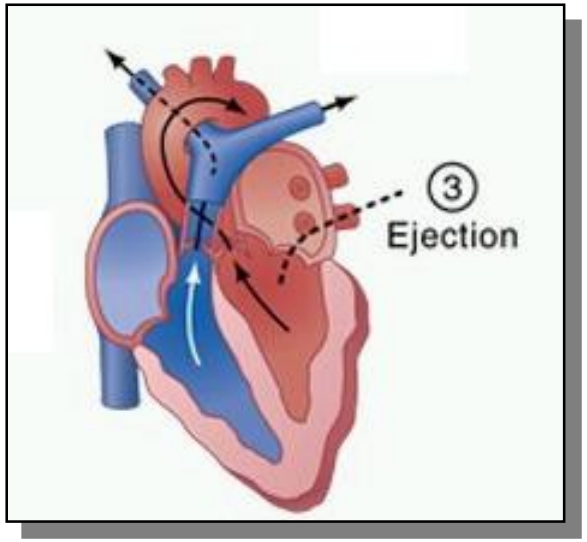
Isovolumetric Ventricular Contraction

- 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



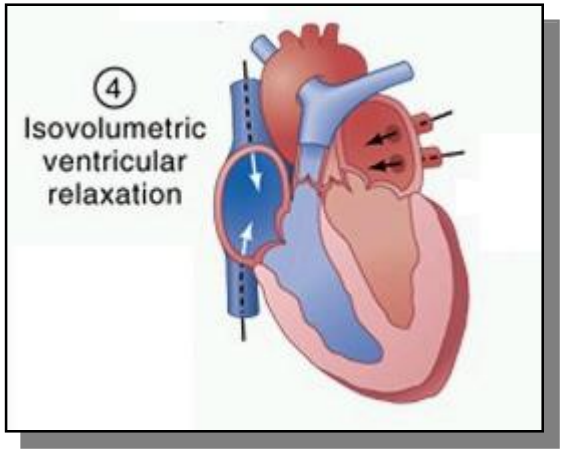
Ejection

- 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



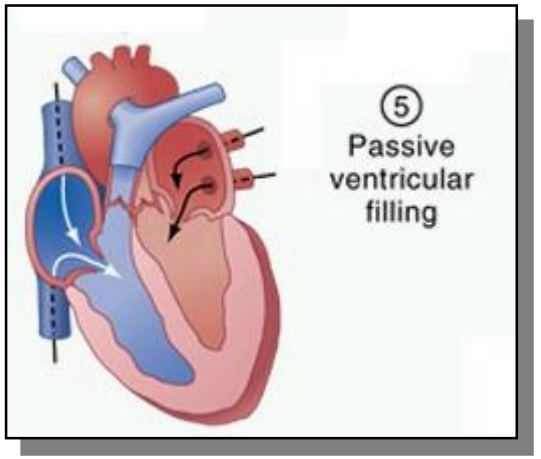
Isovolumetric Ventricular Relaxation

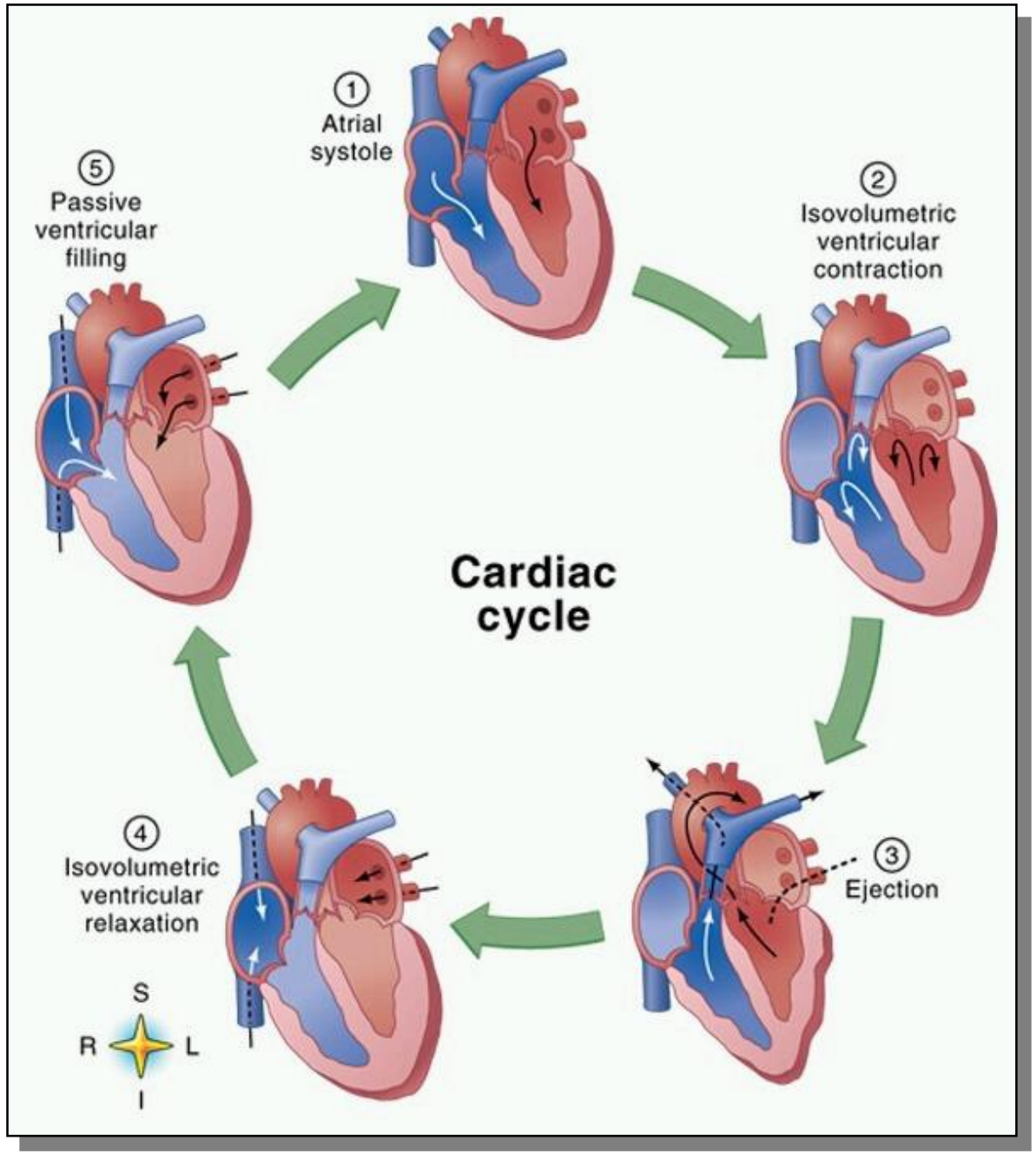
- Atria relax and begin refilling (atrial diastole)
- Ventricular diastole begins in this phase
- Identified by the closure of the SL valves and opening of the AV valves
  - Note pressure in the atria must exceed the ventricles for the valves to open
- Interventricular pressure decreases while volume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

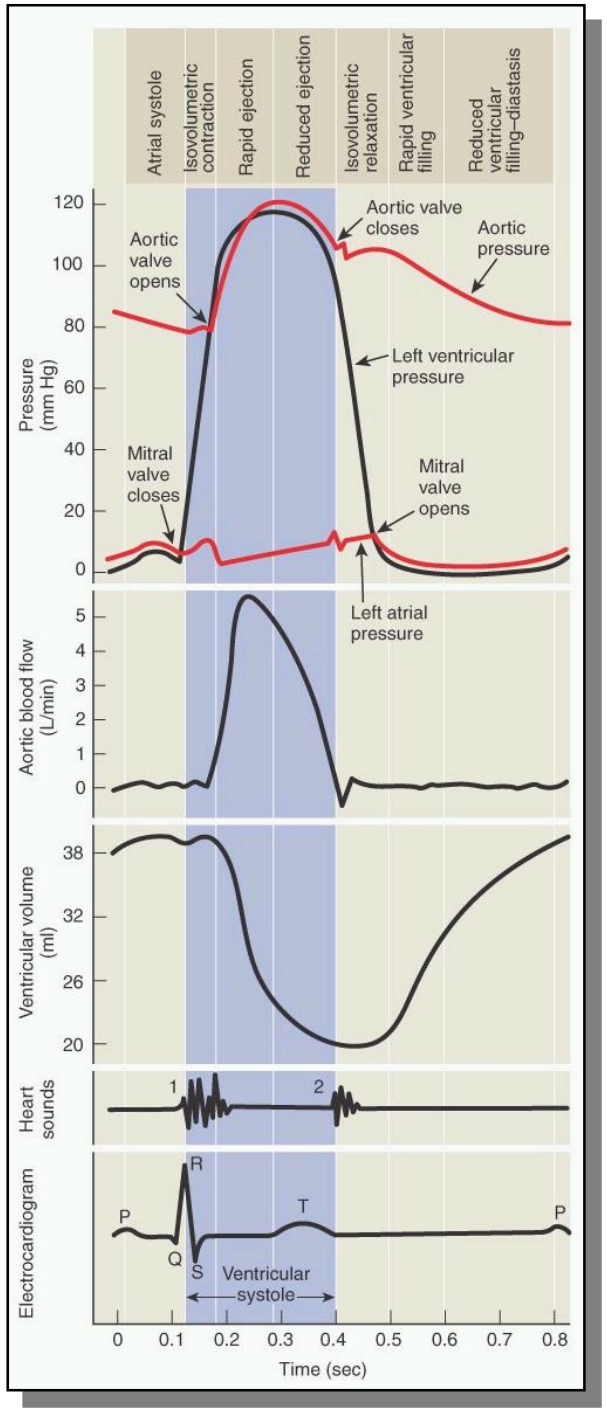


Passive Ventricular Filling

- 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

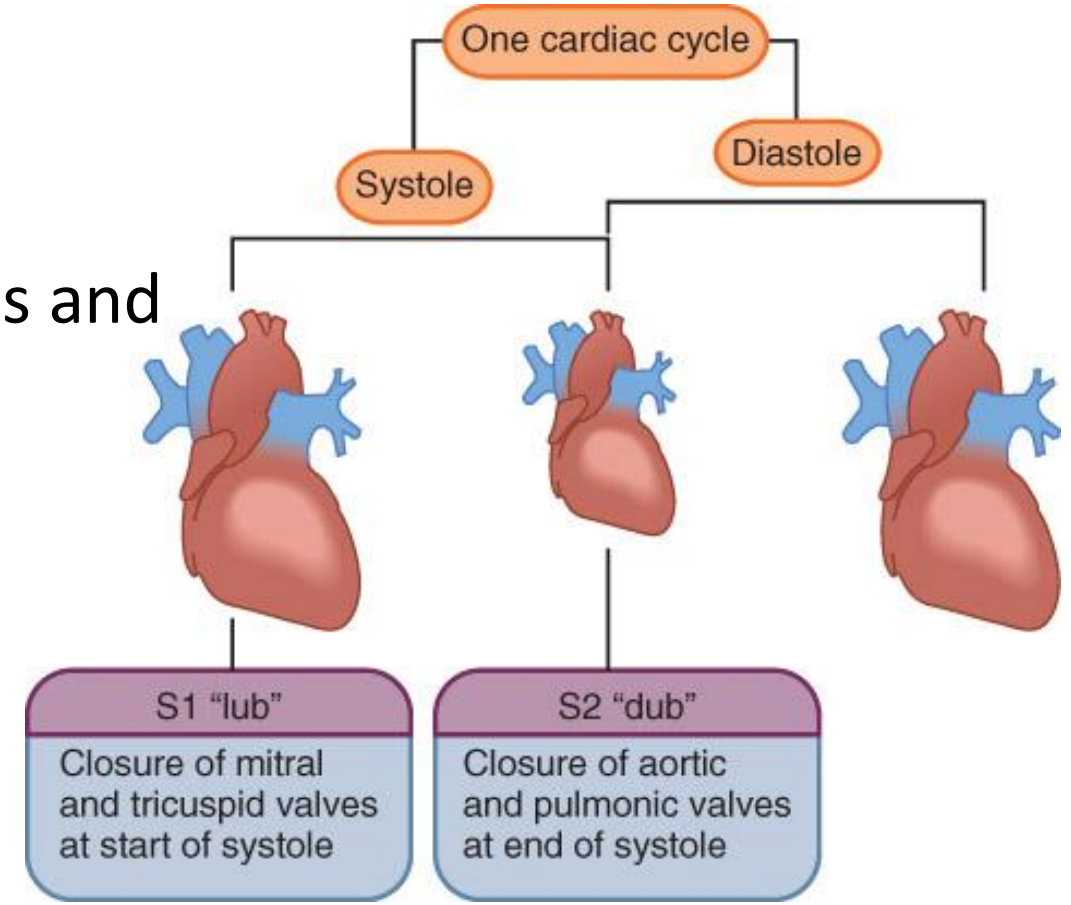



1
Atrial systole
2
Isovolumetric ventricular contraction
3
Ejection
4
Isovolumetric ventricular relaxation
5
Passive ventricular filling
Cardiac cycle
S
R
L
I


Atrial systole
Isovolumetric contraction
Rapid ejection
Reduced ejection
Isovolumetric relaxation
Rapid ventricular filling
Reduced ventricular filling–diastasis
Pressure (mm Hg)
120
100
80
60
40
20
0
Aortic valve opens
Aortic valve closes
Aortic pressure
Left ventricular pressure
Mitral valve closes
Mitral valve opens
Left atrial pressure
Aortic blood flow (L/min)
5
4
3
2
1
0
Ventricular volume (ml)
38
32
26
20
Heart sounds
1
2
Electrocardiogram
R
P
Q
S
T
P
Ventricular systole
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Time (sec)

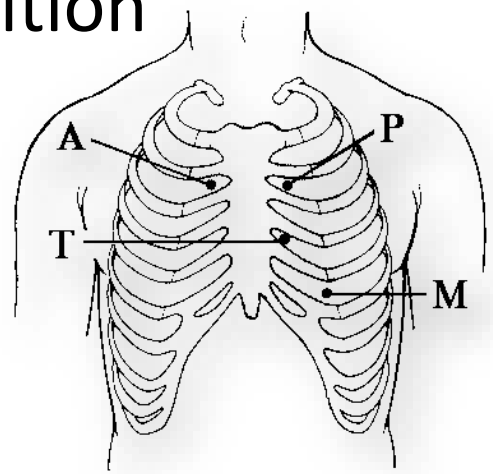
Heart Sounds

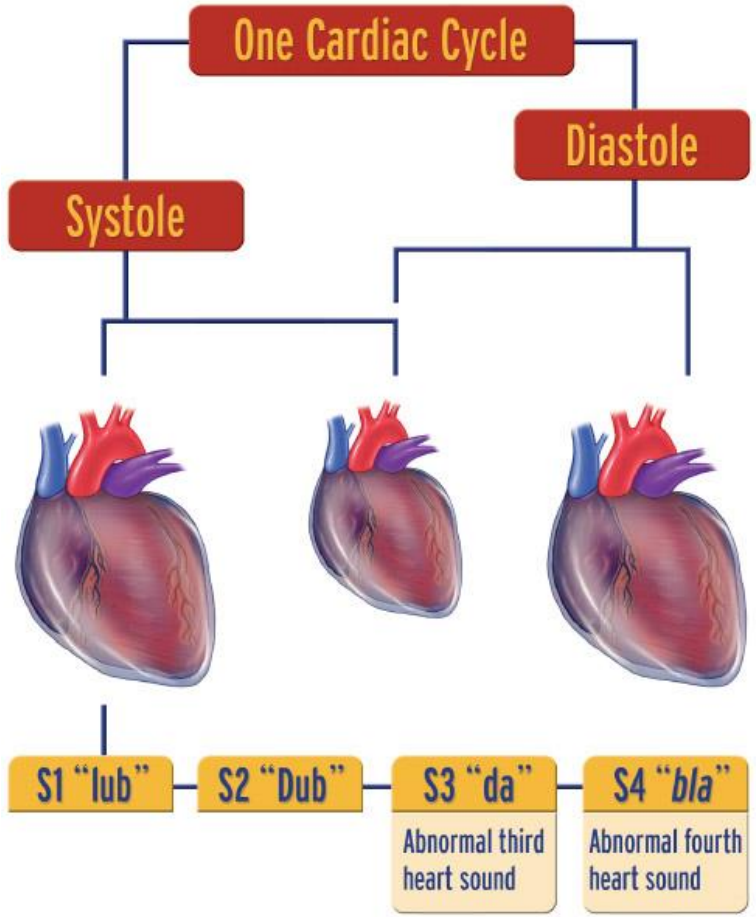
- Sounds made during the cardiac cycle
- Usually described as “lubb-dubb”
- First (S1)
  - Caused by contraction of the ventricles and closure of the AV valves
  - Longer and lower then second
- Second (S2)
  - Caused by closure of the SL valves
  - Shorter and sharper then the first



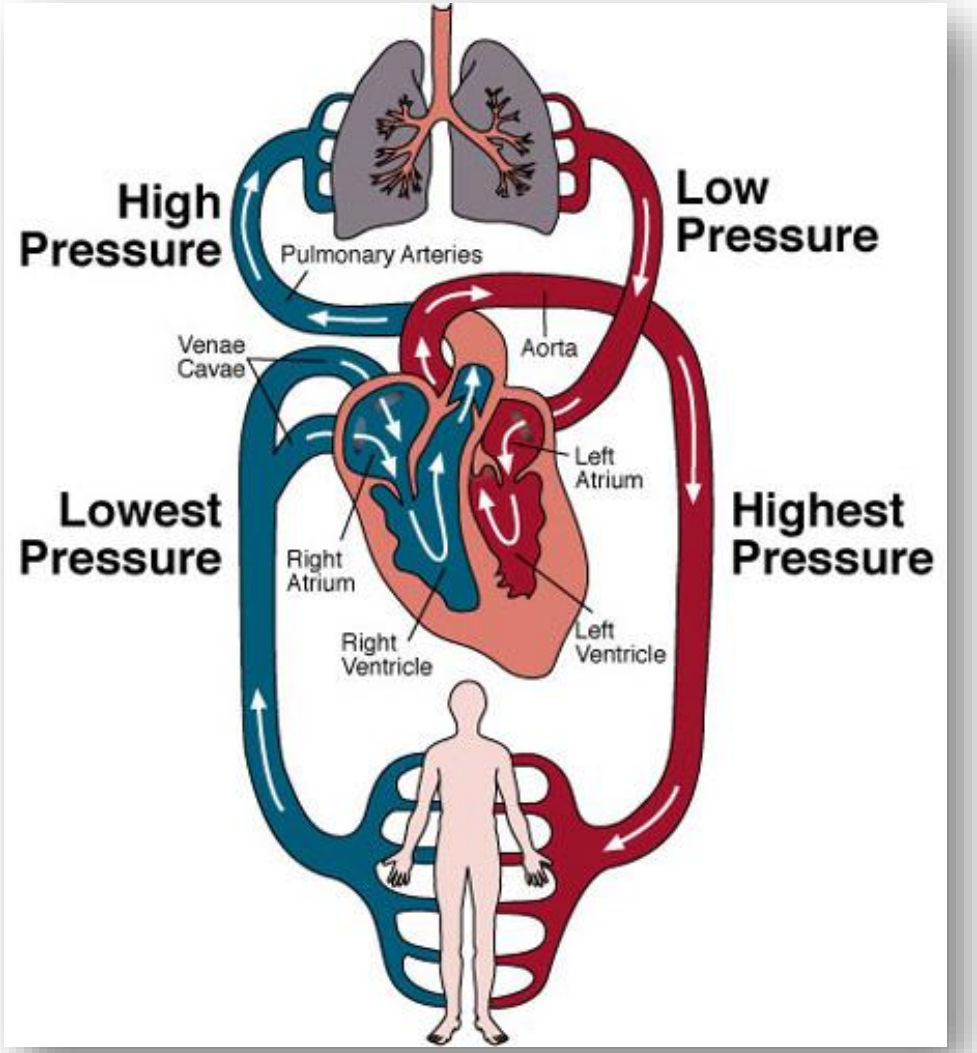
Heart Sounds

- 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

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

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

$$= 93.3$$

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

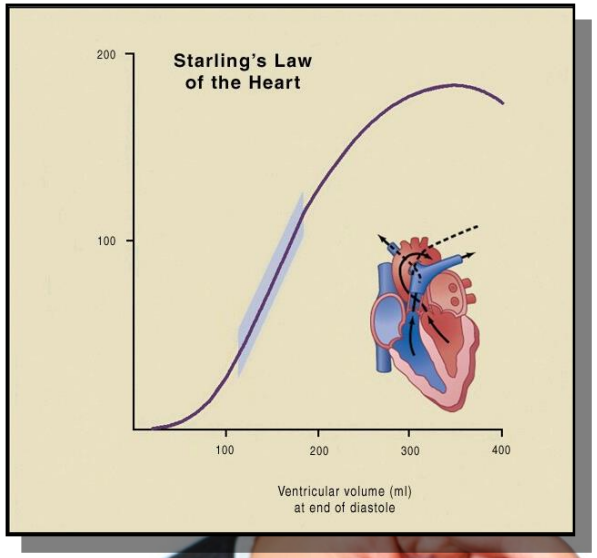
$$= 80 + \frac{(120\ - 80)}{3}$$

$$= 93.3$$

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

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

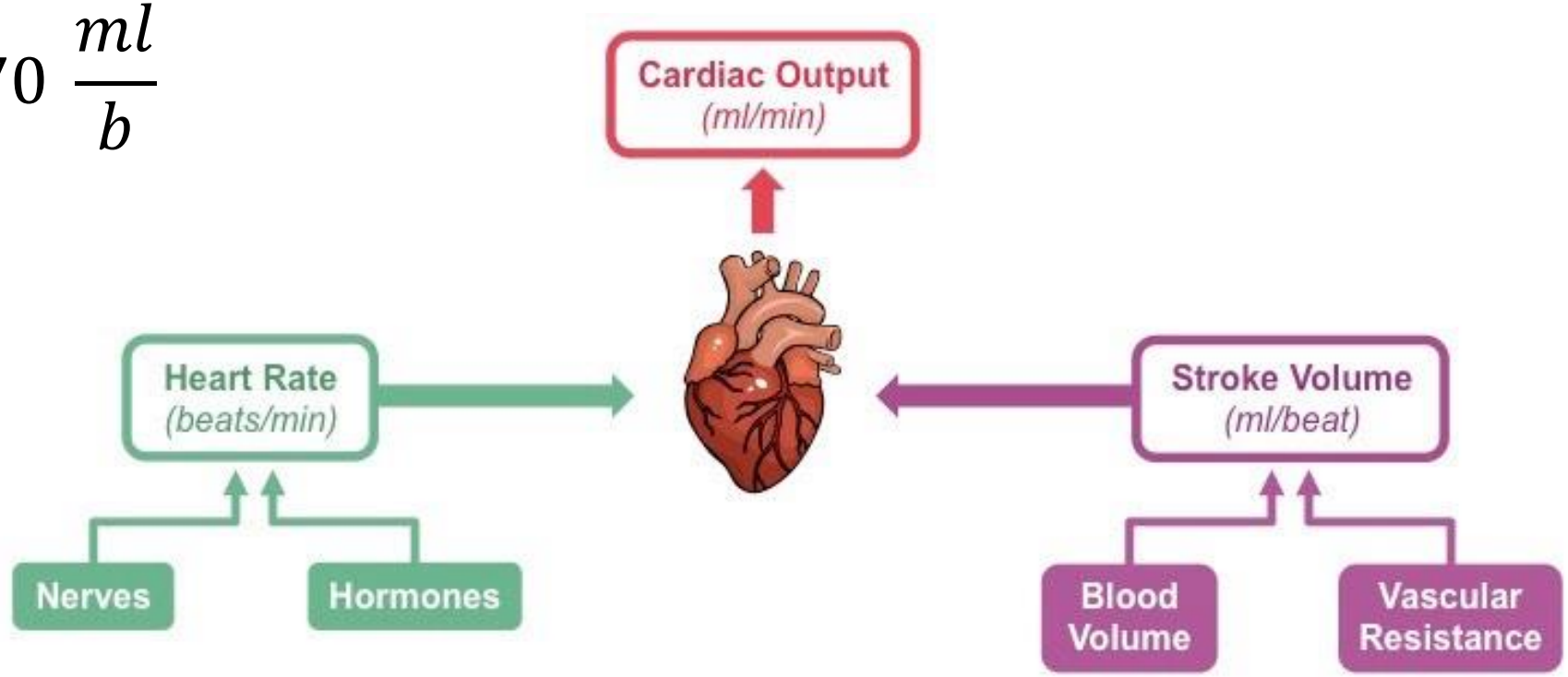
Cardiac Output

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

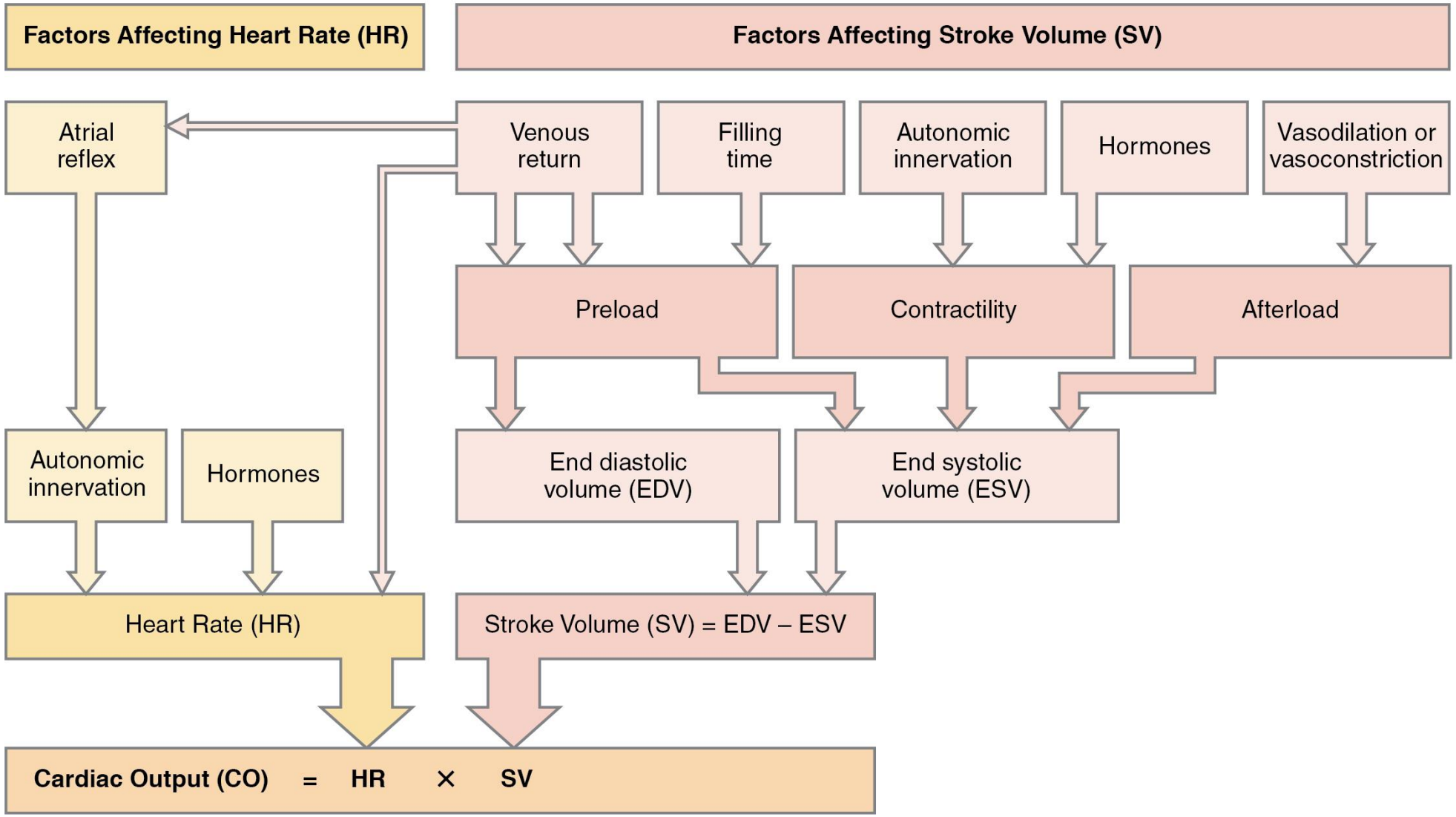
$$CO = HR\ X\ SV$$

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

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



Cardiac Output



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

- The pressure in the aorta against which the left ventricle must pump blood (Result of PVR)
- The greater the afterload, the harder it is for the ventricle to eject blood into the aorta, reducing the stroke volume
- ↑ PVR = ↓ SV
  - Due to ↑ aortic pressure and the ventricles now must overcome this pressure first
- ↓ PVR = ↑ SV
  - If sufficient enough volume is present

Terminology

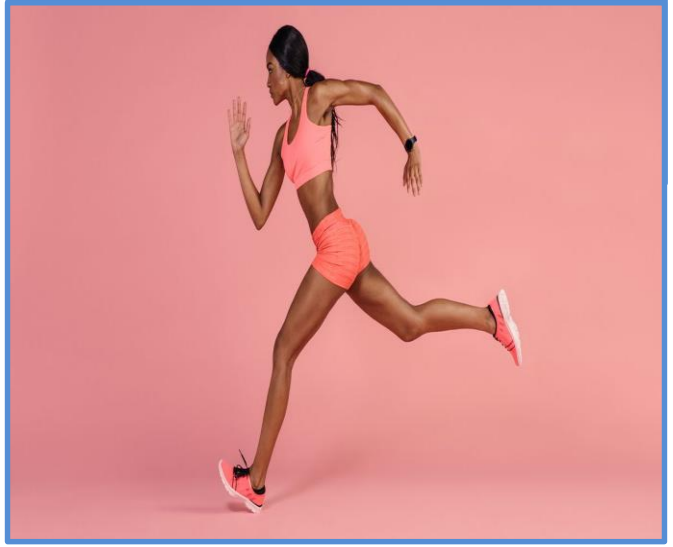
Chronotropy

Refers to heart rate

Inotropy

Refers to contractile strength

Dromotropy



Refers to rate of nerve impulse conduction (AV node)

Venous Return

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