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GPAT Online Class for B Pharm students

Human Anatomy and Physiology part -1

(Cardiovascular system)

By

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Blood Vessels

The cardiovascular system has three types of blood vessels:

Arteries (and arterioles) – carry blood away from the heart

Capillaries – where nutrient and gas exchange occur

Veins (and venules) – carry blood toward the heart.

Arteries

Arteries and arterioles take blood away from the heart. The largest artery is the aorta. The middle layer of an artery wall consists of smooth muscle that can constrict to regulate blood flow and blood pressure.

Arterioles can constrict or dilate, changing blood pressure.

The Capillaries

Capillaries have walls only one cell thick to allow exchange of gases and nutrients with tissue fluid. Capillary beds are present in all regions of the body but not all capillary beds are open at the same time.

The Veins

Venules drain blood from capillaries, then join to form veins that take blood to the heart. Veins have much less smooth muscle and connective tissue than arteries

Veins often have valves that prevent the backward flow of blood when closed. Veins carry about 70% of the body's blood and act as a reservoir during hemorrhage.

Structure of Vessels

- Arteries, veins and capillaries differ in structure.
- Three layers are found in arteries and veins.
- The outermost layer = tunica externa or adventitia. It is made of connective tissue fibers to reinforce the walls under pressure.
- The tunica media is the smooth muscle middle layer. It is much thicker in arteries than in veins and contains a thin layer of elastic tissue. This layer is under control of the ANS and maintains BP and blood distribution.

- The tunica intima lines the arteries and veins. It is a single layer of squamous epithelial cells called endothelium that lines the inner surface of the entire cardiovascular system.

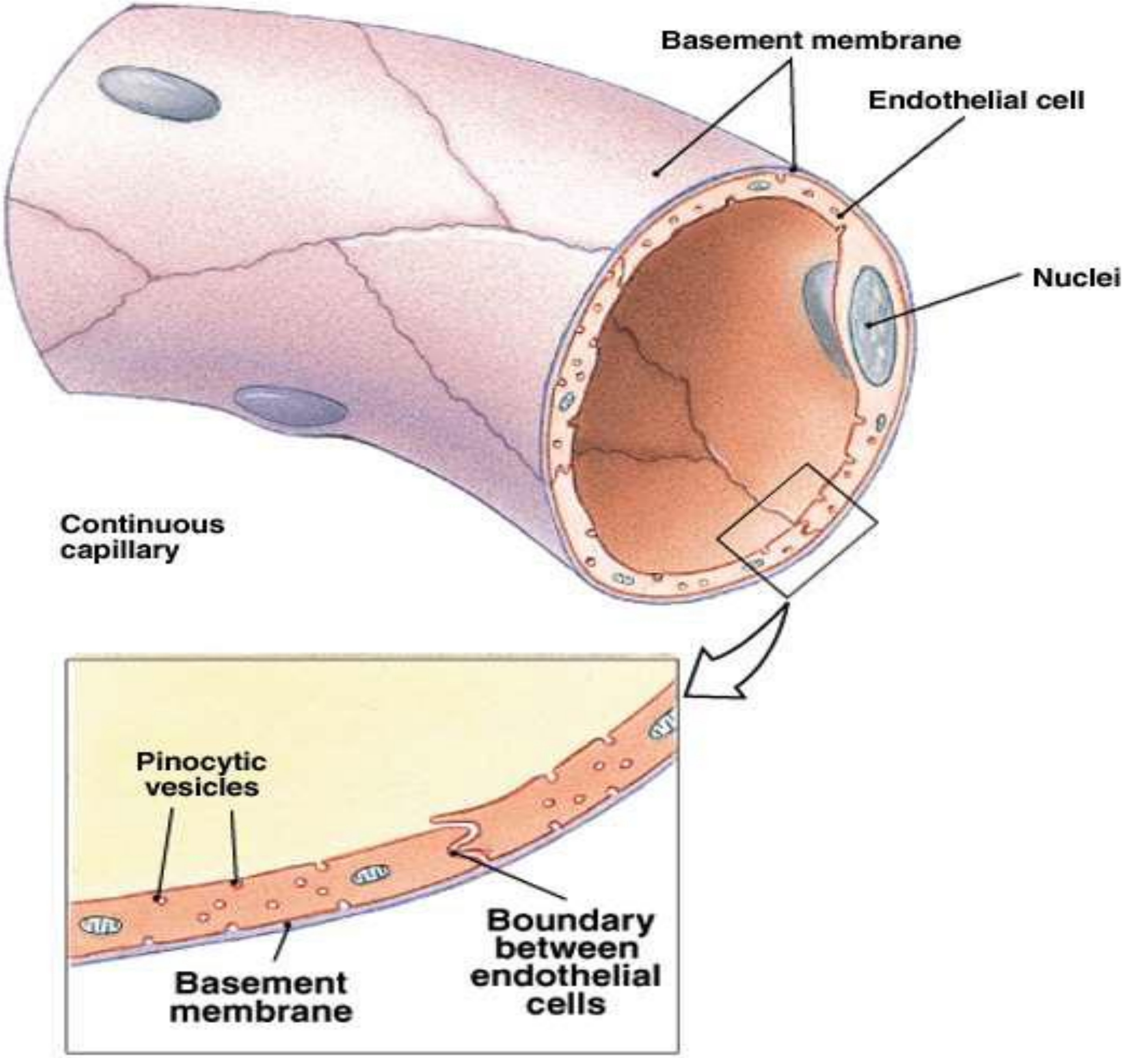
- Large arteries are termed conductance or elastic arteries because the tunica media has less smooth muscle and more elastic fibers
- Medium sized arteries are termed the nutrient arteries because they control the flow of blood to the various regions of the body
- Arterioles have a thin tunica intima and adventitia, but a thick tunica media composed almost entirely of smooth muscle and control blood flow to the capillary bed

Capillary

Pre-capillary sphincter valves

Smooth muscle rings at the proximal end of the capillary

- Contraction decreases blood flow
- Relaxation increases blood flow
- Responsive to local changes in PaO_2, $PaCO_2$, pH and temperature
- Called exchange vessels because they are the site of gas, fluid, nutrient, and waste exchange


Basement membrane
Endothelial cell
Nuclei
Continuous capillary
Pinocytic vesicles
Basement membrane
Boundary between endothelial cells

Venous system

- Transport deoxygenated blood back to the heart – exception: pulmonary vein
- Composed of the same layers as arteries, but are thinner Called capacitance or reservoir vessels because 70% to 75% of the blood volume is contained in the venous system
- Peripheral veins contain one-way valves
- Valves are formed by duplication of endothelial lining
- Found in veins >2mm in diameter

The Heart

The heart is a cone-shaped, muscular organ located between the lungs behind the sternum.

The heart muscle forms the myocardium, with tightly interconnect cells of cardiac muscle tissue.

Layers of the heart

- The heart resides in the pericardium

  A loose membranous sac
- Epicardium

  Continuous with the pericardium
- Myocardium

  Composed of bands of involuntary striated muscle fibers
- Endocardium
- Thin layer of tissue lining the inside of the heart

Chambers of the heart

Atria

Thin-walled upper chambers

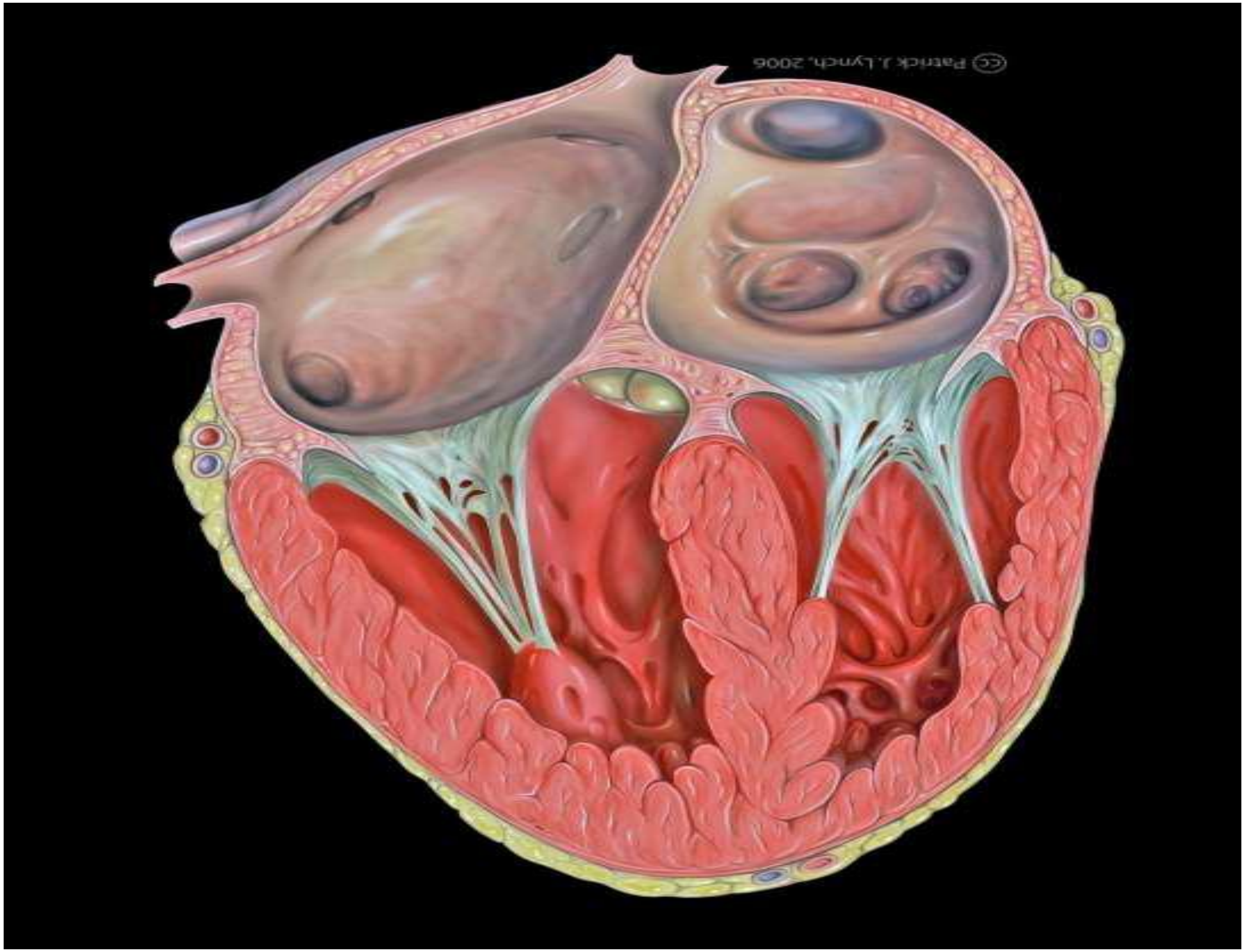
Separated by atrial septum

Act as receiving chamber for blood returning from the body and lungs

Ventricles

Lower chambers which make up the bulk of the muscle mass of the heart

Blood exits from the ventricles into arteries – pulmonary and aorta. The ventricles are referred to as discharging chambers


Patrick J. Lynch, 2006

Valves of the heart

- The two valves that separate the atrial chambers above from the ventricular chambers below are called the atrioventricular valves (AV).
- The right AV valve is called the tricuspid valve. It consists of three leaf-like valve components.
- The left AV valve is called the bicuspid or mitral valve. It consists of two leaf-like valve components.
- Both AV valves prevent the backflow of blood into the atria when the ventricles contract.

- String like structures called chordae tendineae attach the AV valves to the walls of the ventricles via papillary muscles extending from the floor of the ventricles.
- The semilunar valves (SL) valves are located between the two ventricular chambers and the arteries that carry blood away from the heart when systole occurs.
- The ventricles contract at the same time like the atria. The two SL valves open and close at the same time.
- The pulmonary SL valve is located at the beginning of the pulmonary artery and opens to allow blood to enter pulmonary circulation. The valve closes to prevent backflow of blood into the right ventricle.

- The aortic SL valve is located at the beginning of the aorta. The valve opens to allow blood to enter systemic circulation.
- It closes to prevent backflow of blood from the aorta into the left ventricle.

Passage of blood through the heart

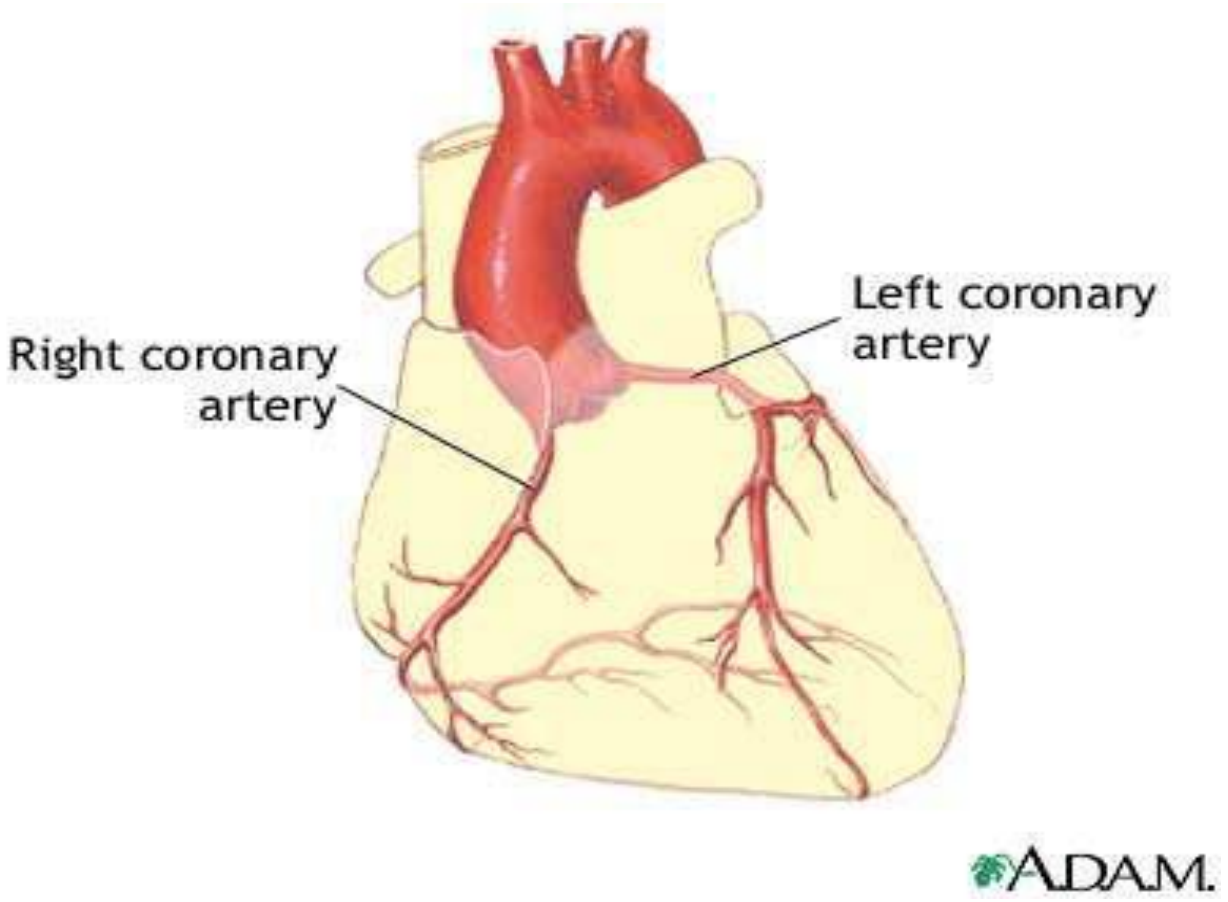
Heart: superior and inferior vena cava → right atrium → tricuspid valve → right ventricle → pulmonary semilunar valve → pulmonary trunk and arteries to the lungs → pulmonary veins leaving the lungs → left atrium → bicuspid valve → left ventricle → aortic semilunar valve → aorta → to the body.

- The heart must perform a great amount of work by pumping through the pulmonary and systemic systems.
- It requires a constant supply of oxygen and nutrients via the coronary circulation to perform this task.

- The heart acts as two separate pumps.
- The right side of the heart pumps blood into the pulmonary system.
- The left side of the heart pumps blood into the systemic circulation.
- Blood enters the right atrium through two large veins called the vena cava. The superior and the Inferior vena cava provides the right atrium with blood.
- The blood leaving the right ventricle is deoxygenated. However it enters the pulmonary circulation via the pulmonary arteries.

- It is returned as oxygenated blood to the right atrium via four pulmonary veins.
- The blood returning to the left atrium crosses the mitral valve and enters the ventricle during atrial contraction.
- When the ventricles contract the left AV valve closes and the blood is pushed into the aortic SL valve – into systemic circulation.

- Blood flows into the heart via the right and left coronary arteries. The location of the openings to these arteries are behind the aortic valve. The openings are called ostia.
- When the aortic valve closes after ventricular systole, blood can flow in a retrograde manner into the coronary arteries.


Right coronary artery
Left coronary artery
A.D.A.M.

Heart is supplied by two coronary arteries.

The right and the left coronary arteries are branches of the ascening aorta.

Right coronary artery	Left coronary artery
1)It is smaller than the left. 2)branches-1)marginal 2)post. interventricular 3)Area supplied- Rt. Atrium Greater part of rt. Ventricle. Smaller part of left ventricle. Post. Part of interventricular septum. Entire conducting sytem except left branch of the A.V. bundle.	1)It is larger than the right. 2)Branches-1)branches to the inferior surface.2)ant. interventricular 3)Area supplied- Left atrium Small part of rt. Ventricle. Greater part of left Ventricle Ant. Part of interventricular septum. Left branch of the A.V. bundle.

- Coronary veins
- Closely parallel the arterial system
- Some coronary venous blood enters the heart through the Thebesian veins
- Thebesian veins (the smallest cardiac veins, present in four chambers of the heart) empty directly into all chambers thus creating some venous admixture lowering Pa02

Myocardial cell structure

- Cells contain myosin, actin, troponin and tropomyosin
- Gap junctions are present at the intercalated disks

  ∴ Entire heart behaves as an electrical syncytium
- Mitochondria are more numerous in cardiac muscles than in skeletal muscles
- **T tubules** – invaginations in the cell membrane. Carry action potentials into the cell interior
- **Sarcoplasmic reticulum** – sites of storage of Ca^{++} needed for excitation-contraction coupling

Steps in excitation-contraction coupling

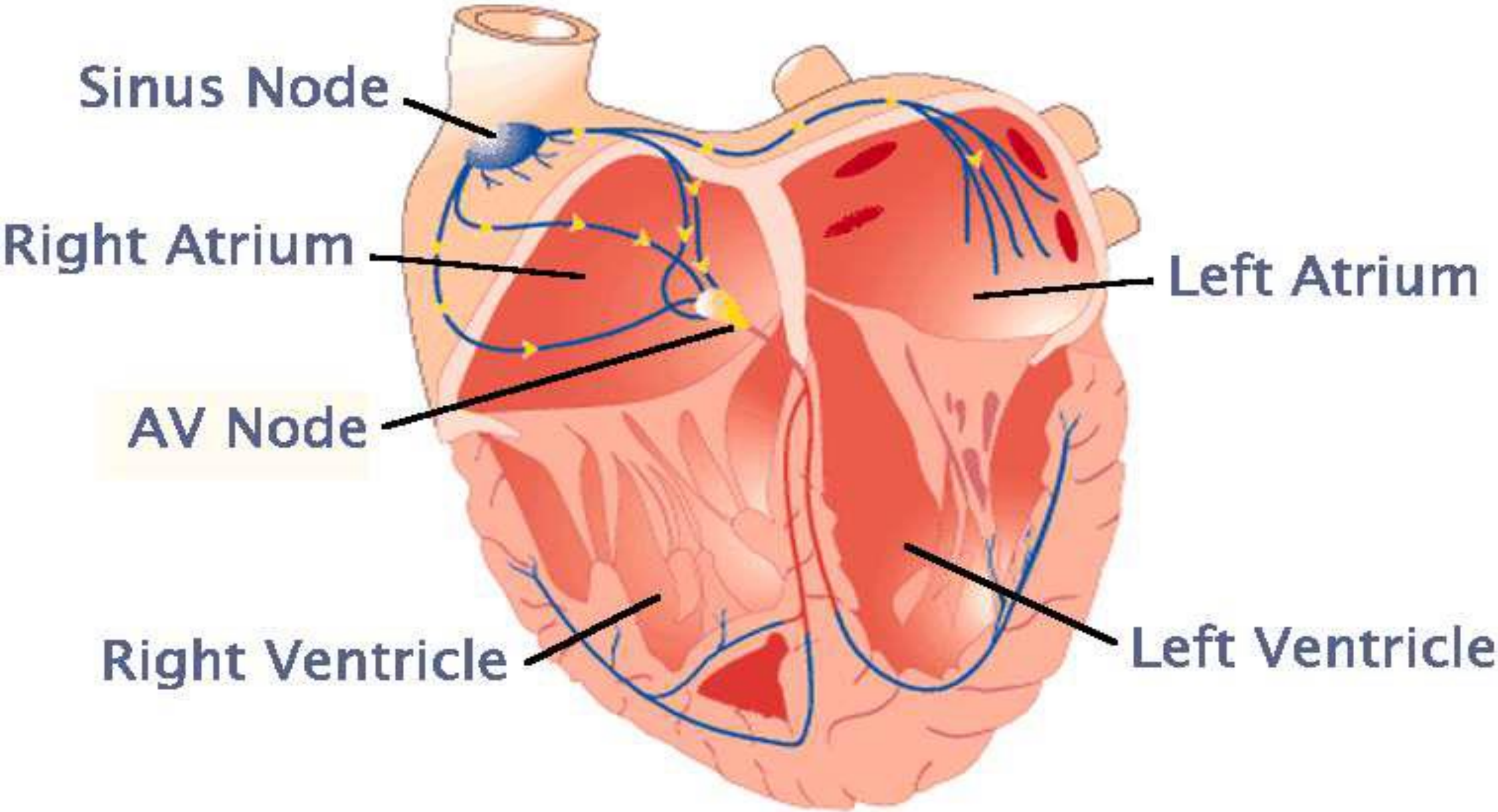
1. Action potential spreads from the cell membrane through the T tubules
2. During the plateau phase of the AP, Ca^{++} enter the cell from the ECF
3. This Ca^{++} entry trigger the release of more Ca^{++} from the SR (Ca^{++} induced Ca^{++} release) – amount released depends on the amount stored and the size of the inward current
4. Intracellular Ca^{++} increase – actin and myosin interaction and contraction occurs
5. The magnitude of tension developed depends on the amount of Intracellular Ca^{++}
6. Relaxation occurs when Ca^{++} is pumped back into SR by Ca^{++} -ATPase pump

Conduction system of the heart

- Cardiac muscle cells have an intrinsic property of contracting on their own.
- The rate of contraction is controlled by the autonomic nervous system.
- The heart has its own conduction system for coordinating contractions during the cardiac cycle.

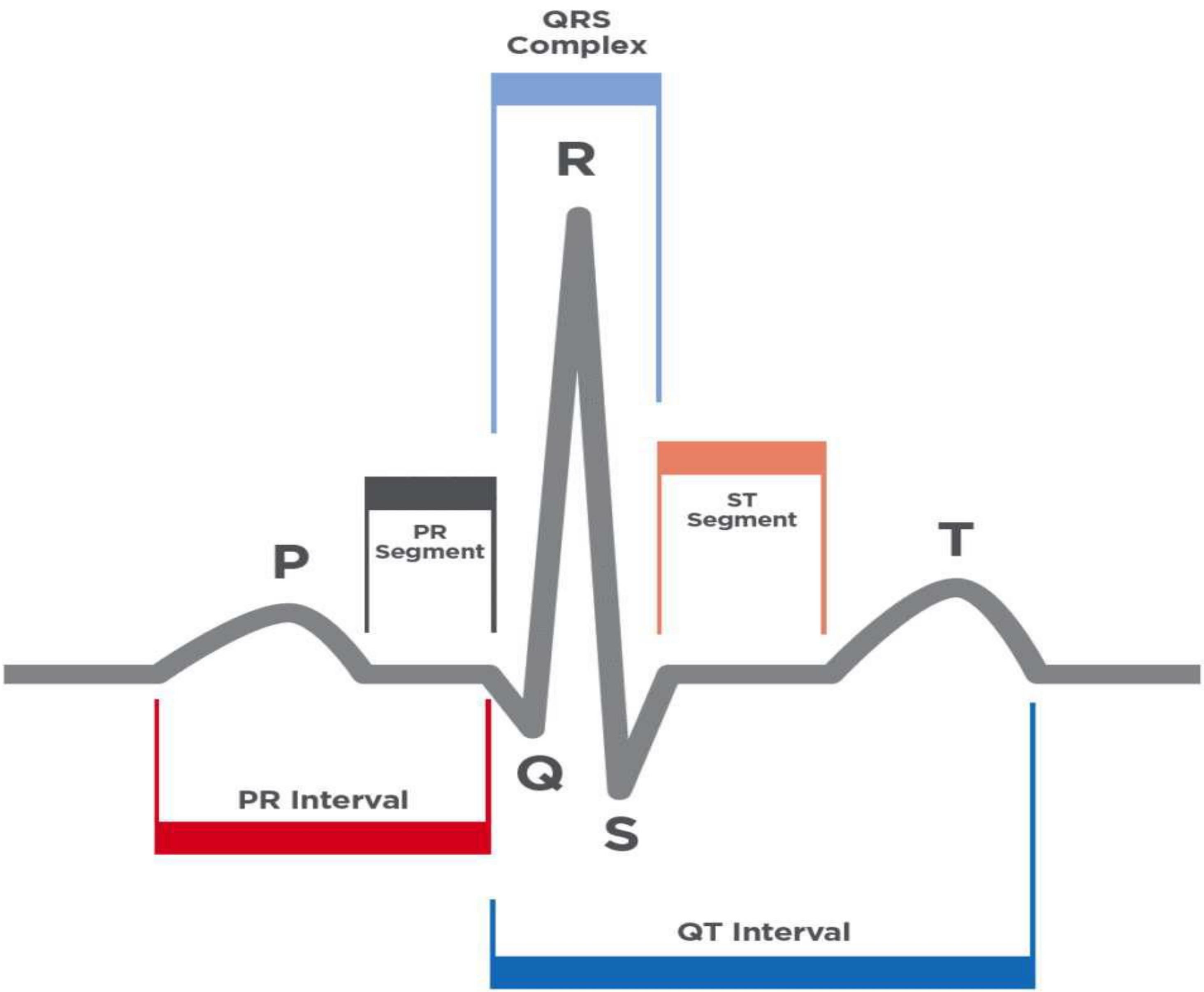
- Intercalated disks are connections that electrically join cardiac muscle fibers into a single unit that allows for impulse conduction through the entire wall of a heart chamber.
- The structures that make of the conduction system of the heart are: Sinoartrial node or pacemaker, Atrioventricular Node (AV node), AV bundle, or bundle of His, Purkinje fibers.

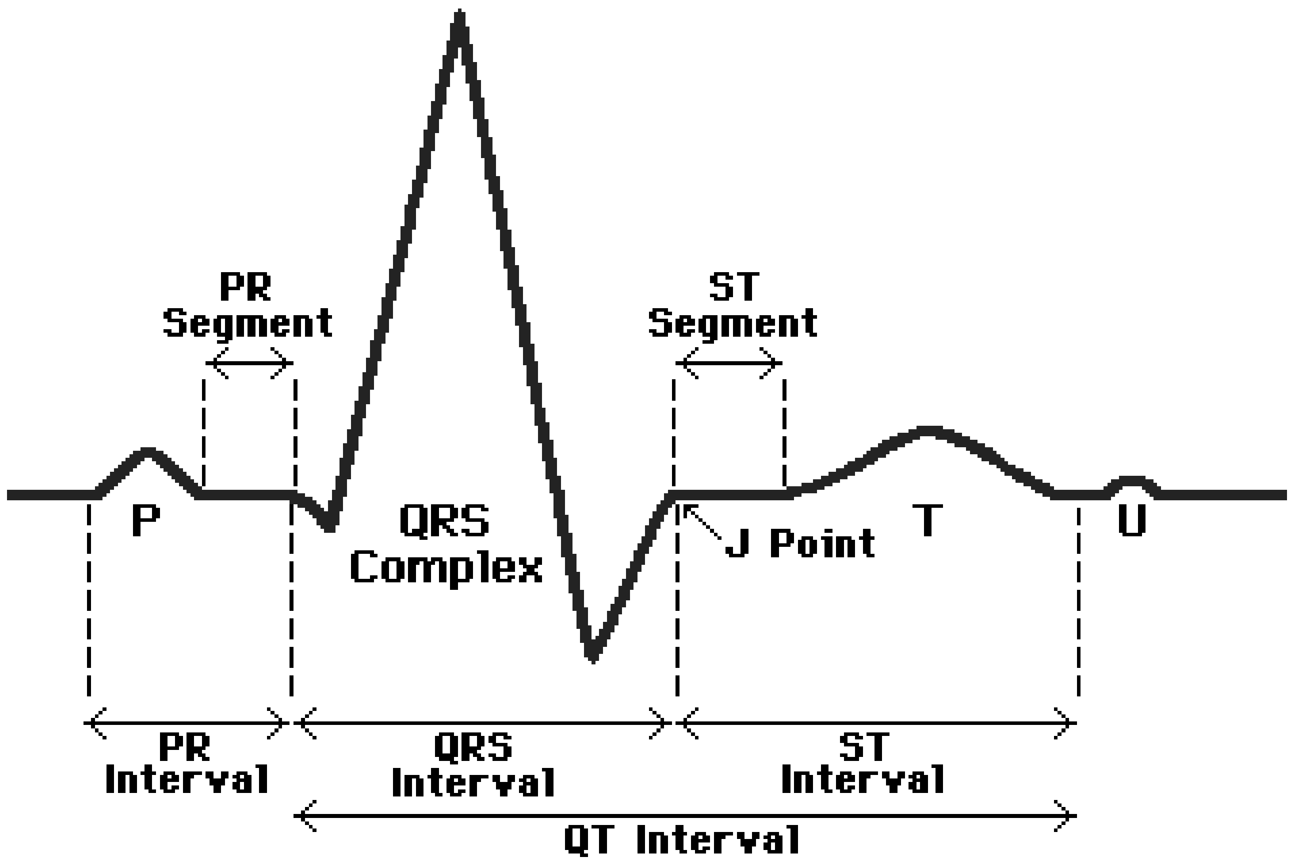
- Impulse conduction starts in the SA node.
- It spreads in all directions through the atria. This causes atrial fibers to contract.
- The pulse will then travel to the AV node and to the AV bundle / bundle of His and to the Purkinje fibers to cause ventricular contraction.
- Normally, therefore a ventricular beat will follow an atrial beat.


Sinus Node
Right Atrium
AV Node
Right Ventricle
Left Atrium
Left Ventricle

The Electrocardiogram

- An electrocardiogram (ECG) is recording of the electrical changes that occur in the myocardium during a cardiac cycle.


QRS
Complex
R
PR
Segment
ST
Segment
P
T
Q
S
PR Interval
QT Interval


PR
Segment
ST
Segment
P
QRS
Complex
J Point
T
U
PR
Interval
QRS
Interval
ST
Interval
QT Interval

Electrocardiogram (ECG)

P wave

- Represents atrial depolarization

PR interval

- Is the interval between the beginning of P wave to beginning of Q wave
- Increases with problems in conduction velocity (heart blocks)
- Varies with heart rate.

QRS complex

- Represents ventricular depolarization

Electrocardiogram (ECG)

QT interval

- From beginning of QRS to end of T wave
- Represents entire ventricular depolarization and repolarisation

ST segment

- Is the segment from the end of S wave to the beginning of T wave
- Is isoelectric
- Represents the period when the ventricle is depolarized

T wave

- Represents ventricular repolarisation

P wave – Atrial depolarization, spreads from the RA to the LA.

Normal value = 80ms

PR Segment – Impulse does not produce contraction, it is traveling toward ventricles. Normal = 50 to 120 ms.

PR Interval – The time it takes for the impulse to travel from the SA node to the AV node where it then enters the ventricles. The normal value is 120-200 ms.

QRS Complex – Rapid depolarization of right and left ventricles. Normal Ranges = 80 to 120 ms.

- Shorter QRS values are found in children and in rapid states of heart beat – tachycardia.
- Prolonged values = hyperkalemia or bundle branch block.
- J Point – Point at which QRS ends and ST segments begins.
- ST segment = ventricles are depolarized. Normal = 80 to 120
- ms
- T wave = 160 ms ventricles relax.

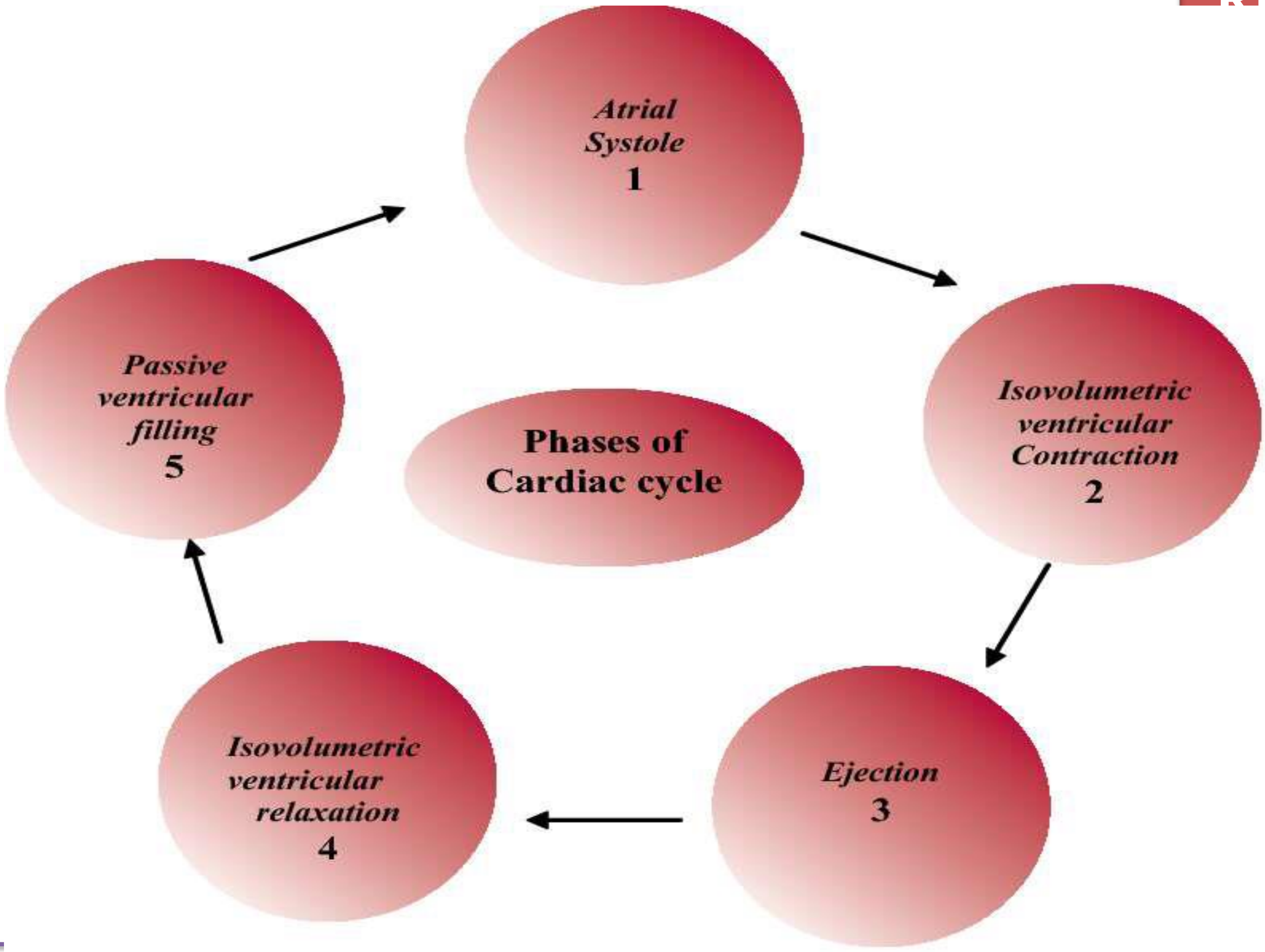
ST interval – Measured from J point to end of T wave. Normal = 320 ms. Represents slow phase of ventricular repolarization.

QT interval – Measured from beginning of QRS to end of T. Normal = up to 420 ms in heart rates of 60 bpm.

Prolonged QT = ventricular tachyarthmias and sudden death.

Cardiac cycle

- The normal beating of the heart is regular and in a specific rhythm.
- Each complete heartbeat is called a cardiac cycle and includes systole and diastole (contraction and relaxation).
- Each cycle takes about 0.8 seconds to complete if the heart is beating at a rate of 72 beats per minute.
- Stoke Volume (SV) = the volume of blood ejected from the ventricles during each beat.


Atrial Systole 1
Isovolumetric ventricular Contraction 2
Ejection 3
Isovolumetric ventricular relaxation 4
Passive ventricular filling 5
Phases of Cardiac cycle

Velocity of blood flow

- Can be expressed by:

$$V = Q / A$$

v = velocity (cm/sec)

Q = blood flow (ml/min)

A = cross sectional area (cm^2)

- Therefore,

velocity is higher in the aorta (smaller cross sectional area)

is lower in all the capillaries – Why ?

Mean velocity of blood flow – lowest on the capillaries

To maximize the exchange of substances

Cardiac Output (CO) = the volume of blood pumped by one ventricle per minute.

CO = HR x SV

Normal CO = 5 L/min

Question in gpat (Definition)

Stroke volume

- Is the volume of blood ejected from each ventricle on each beat
- Expressed by the following:

  Stroke volume = EDV – ESV

- Normally is about 70 ml

  (as EDV = 140 ml & ESV = 70 ml)
- SV = (~2 x pulse pressure)

End-systolic volume (ESV)

Volume remaining after systole

End-diastolic volume (EDV)

Volume to which the ventricles fill during diastole

Ejection fraction (EF)

- Proportion of EDV ejected on each stroke

EF = SV/EDV

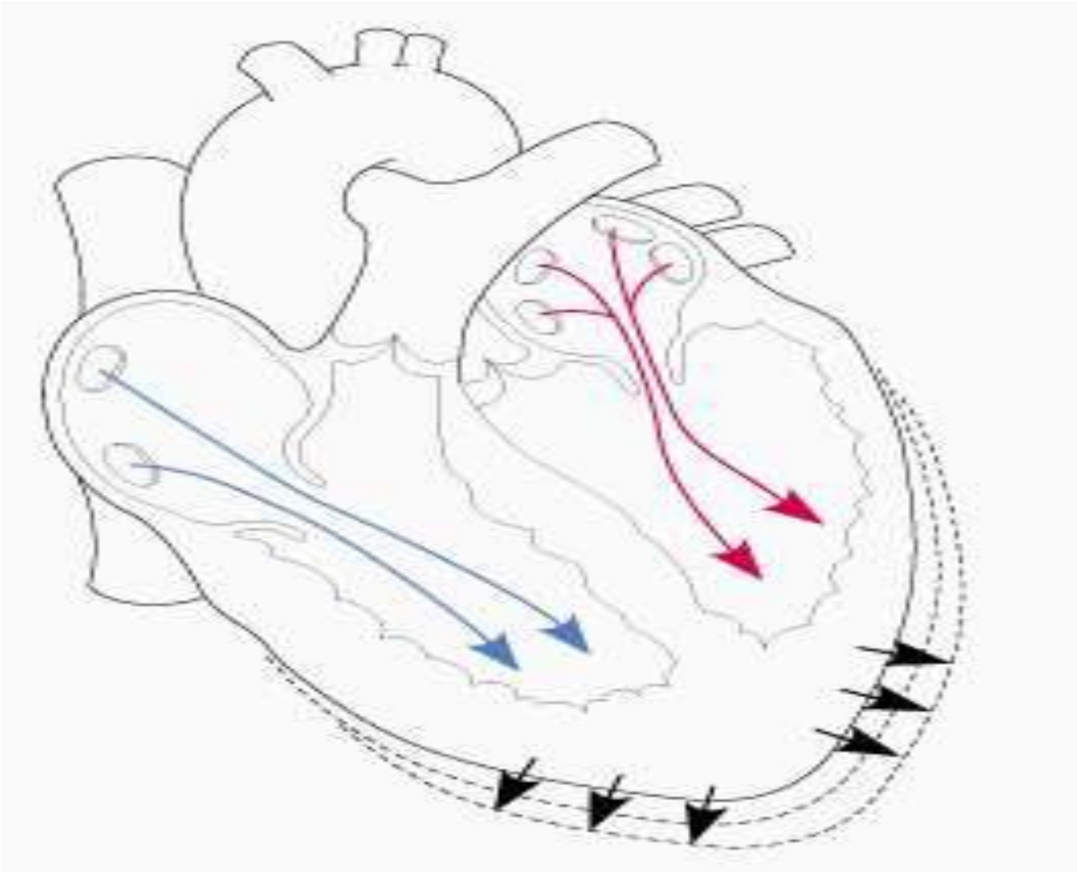
- Normal value – 64%

Regulation of stroke volume is by three factors

- **PRELOAD**
- **CONTRACTILITY**
- **AFTERLOAD**

Preload

- Stretch of cardiac muscle prior to contraction.
- Preload is proportional to End Diastolic Volume.



(a) Preload

Contractility

- It is the strength of contraction at any given preload.
- Positive and Negative inotropics
- Stimulation of sympathetic division of ANS leads to positive inotropic effect
- Inhibition of sympathetic division of ANS leads to negative inotropic effect

Afterload

The pressure that must be overcome before a semilunar valve can open is termed the afterload.

Increase in afterload causes decrease in stroke volume

HTN and atherosclerosis increases the afterload.

Afterload

Left ventricle = Aortic pressure.

Right ventricle = Pulmonary artery pressure.

Heart sounds

- Two distinct sounds can be heard on the anterior chest wall.
- They are described as the lub dup sounds.
- The first lub sound is the result of the abrupt closure of the AV valves as the ventricles contract.
- The closure of the AV valves during ventricular systole prevents blood backflow into the atrial chambers.
- The second sound, dup is the closing of both the SL valves during ventricular diastole.

Blood Pressure

Force of blood exerted against the vessel walls

Systolic pressure is high when the heart expels the blood.

- Diastolic pressure occurs when the heart ventricles are relaxing.
- It is the highest in the arteries and the lowest in the veins.
- The blood pressure gradient is the difference between two blood pressures.

- The BP for systemic circulation is the difference of the mean BP in the aorta and the pressure at the termination of the vena cava.
- The mean BP in the aorta is 100 mmHg and within the termination of the vena cava it is 0 mmHg.
- The systemic BP gradient is 100 - 0 = 100 mmHg.
- The BP gradient is responsible for keeping the blood flowing.
- When a BP gradient is not present, blood does not circulate.

- Factors affecting blood pressure
- Blood Volume, Strength of Contraction, Heart Rate
  Thickness of Blood
- Blood Volume – The larger the volume of blood in the arteries, the greater the pressure that is exerted on their walls.
- The lower the volume, the lower the blood pressure

Hemorrhage is a pronounced loss of blood, this decrease in volume causes a decrease in BP.

Diuretics-drugs that promote water loss by increasing urine output.

These drugs are often used to treat HTN by decreasing blood volume

Heart Contractions – Strength and rate of the heartbeat affect CO and therefore BP.

The stronger the contraction, the more blood is pumped into the arteries.

Heart Rate - The rate of the heartbeat also may affect arterial blood pressure.
When the heart beats faster, more blood enters the aorta, and therefore the arterial blood pressure should increase if the SV does not decrease.
Blood viscosity - If blood becomes less viscous than normal, blood pressure will decrease. If a person suffers a hemorrhage, fluid moves into the blood from the interstitial fluid. This dilutes the blood and decreases blood pressure.

- Polycythemia is a condition in which the number of red blood cells increase to compensate for low oxygen levels. This can cause an increase in viscosity.

Peripheral Resistance describes any force that acts against the flow of blood in a blood vessel.

Tension of muscles within the walls of blood vessels can affect PR.

- When blood vessel walls are relaxed resistance is low.
- When blood vessel muscles are contracted resistance is high.
- Vasomotor mechanism- adjustment of muscle tension in vessel walls to control blood pressure and blood flow.

Afterload

The pressure that must be overcome before a semilunar valve can open is termed the afterload.

Increase in afterload causes decrease in stroke volume

HTN and atherosclerosis increases the afterload.

Afterload

Left ventricle = Aortic pressure.

Right ventricle = Pulmonary artery pressure.

Previous questions

1. Which of the following is most likely undergo lysis

a) a cell losing water from its cytoplasm

b) a cell with an intact, multilayer peptidoglycan cell wall

c) a cell with disrupted pentaglycine bridges in its cell wall

d) a cell with hydrophilic outermost layer in its cell wall

2. In which part of the GIT mastication takes place

a) Stomach b) oral cavity c) Rectum d) duodenum

3. Largest hip bone

a) calcaneus b)femur c) ischium d)illium

Thank You All