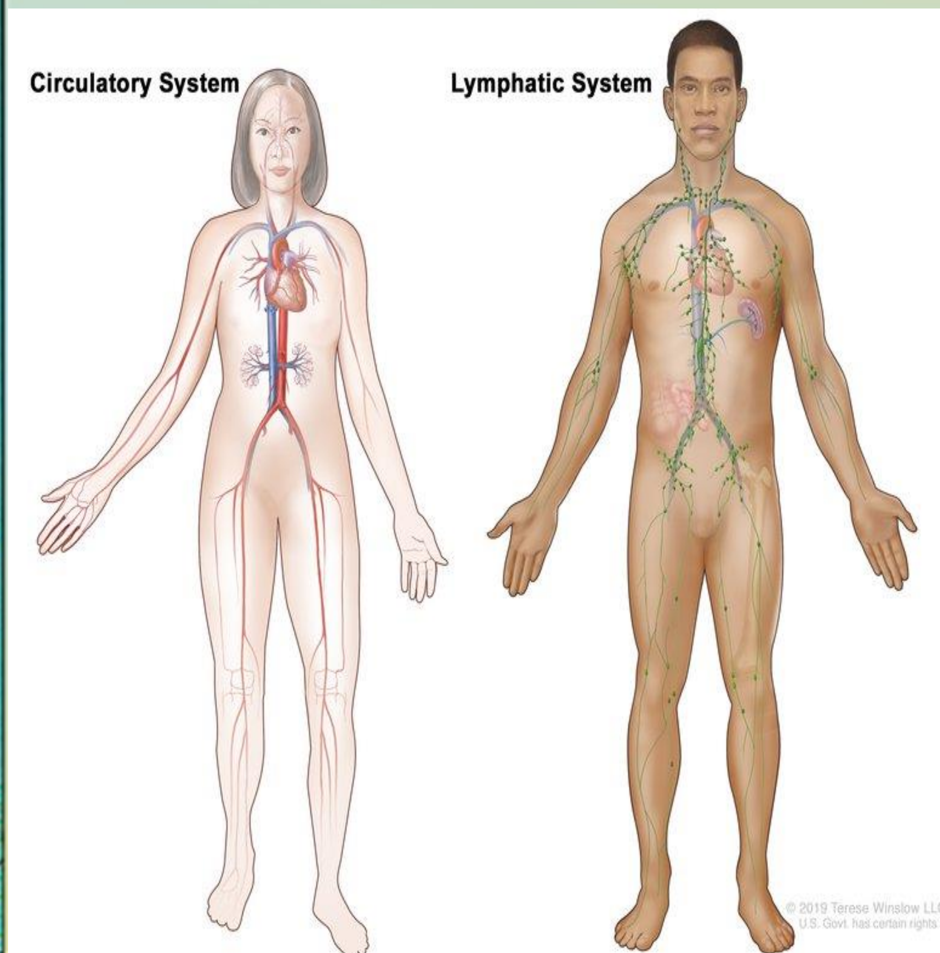
Circulatory and Lymphatic System



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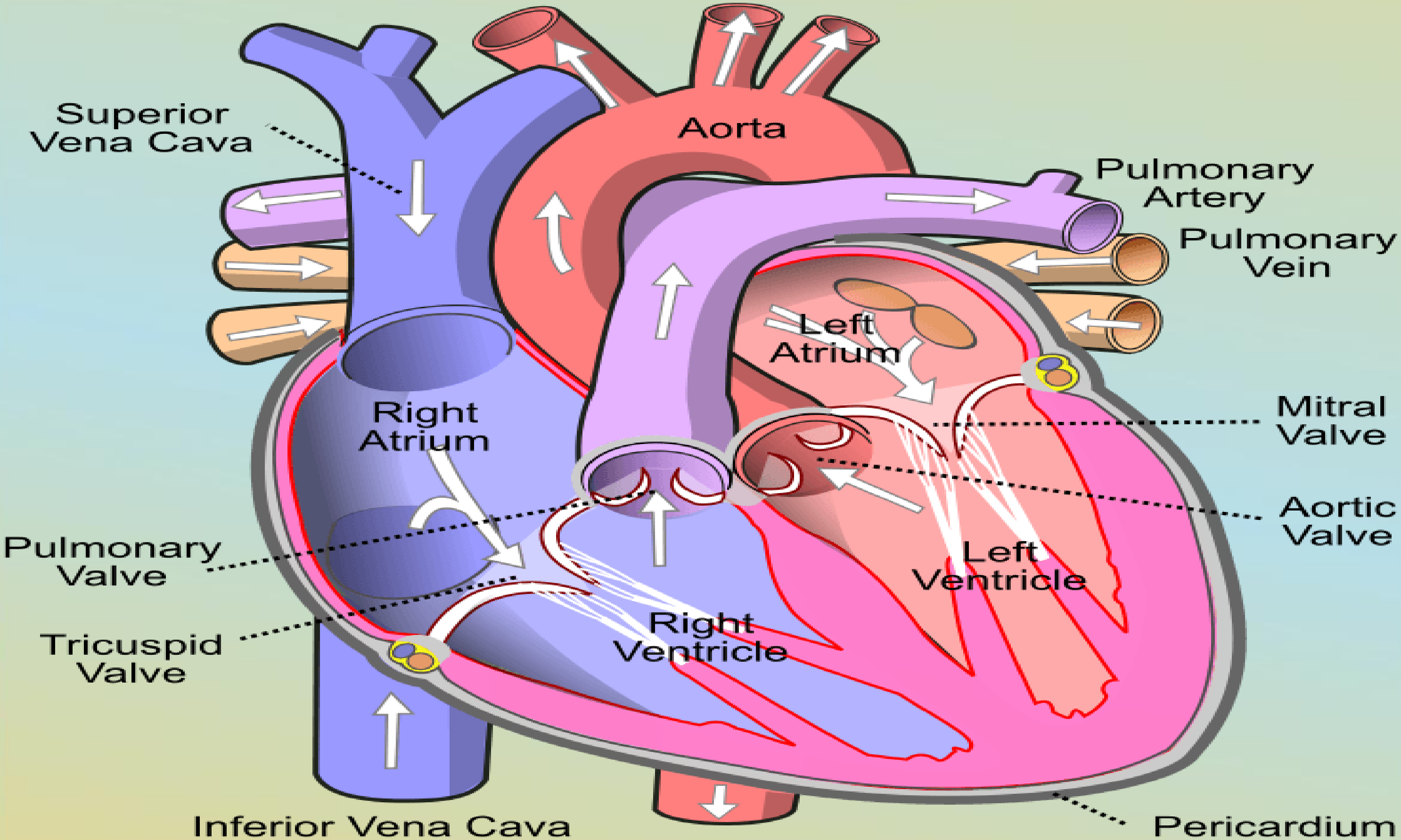
Introduction

The system that fulfils the transportation needs of the body is the cardiovascular system. This system is composed of the heart, blood vessels, and blood.



Main functions of the cardiovascular system are:

1) Distribution of O_2 and nutrients to all the body cells and tissues.

2) Transportation of CO_2 and metabolic waste products (such as urea) from tissues to lungs and other excretory organs.

3) Distribution of water, electrolytes, and hormones throughout the body.

4) Parts of the immune system.

5) Thermoregulation.

Blood is pumped through a muscular organ of the circulatory system called the heart.

It is composed of very strong cardiac muscle tissue, and shows rhythmic contraction and relaxation.

As a result of this contraction and relaxation, a force is generated that pumps the blood to the entire body along with nutrients and oxygen.

The heart performs the following important functions:

1)Pumping blood: The heart pumps blood throughout the body, supplying oxygen and nutrients to all the organs and tissues.

2)Regulating blood pressure: The heart helps regulate blood pressure by adjusting the force and rate at which it pumps blood.

3)Maintaining fluid balance: The heart works with the kidneys and other organs to maintain a healthy balance of fluids in the body.

4)Transporting hormones: The heart also helps transport hor mones and other important substances throughout the body.

5)Providing oxygen to the heart: The coronary arteries supply the heart itself with the blood and oxygen it needs to functio n properly.

6)Removing waste products: The heart also helps remove waste products from the body, such as carbon dioxide and me tabolic waste.

Overall, the heart is an essential organ that plays a crucial role in keeping our bodies healthy an functioning properly.

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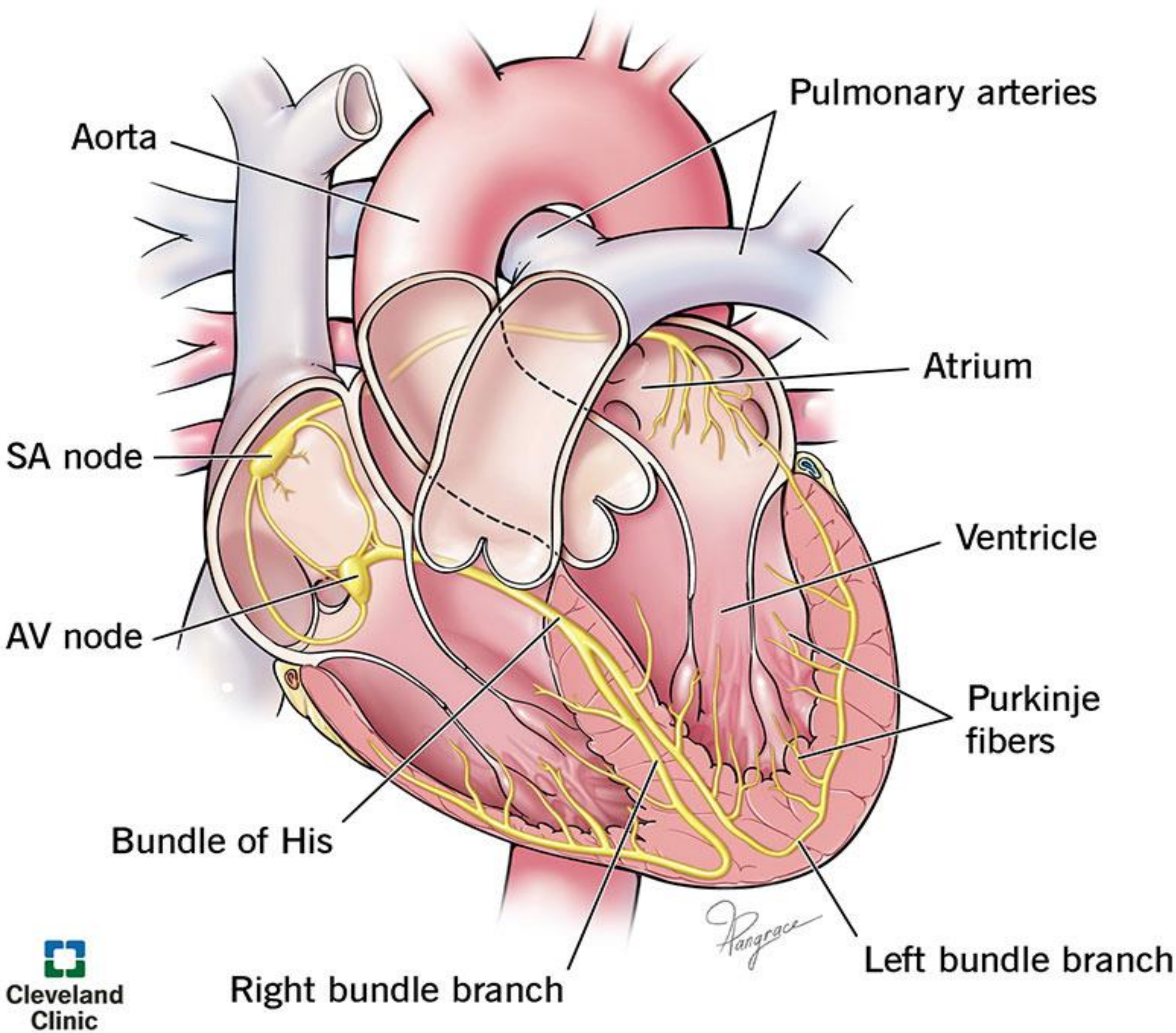

The conduction system of the heart is a specialized electrical system that controls the rhythm and rate of the heartbeat.

Conducting system of the heart includes the following six components

Sinoatrial (SA) Node: It is located in the right atrium, near the opening of the superior vena cava. It is about 1.5cm in length and 0.5cm in width. It is also known as the **pacemaker of heart.**

It comprises of the pacemaker (P) cells and some myofilaments. Impulse is generated by the P cells and then transmitted within the conducting system (with a speed of 0.05m/s) for the excitation and contraction of heart muscles.

Conducting system of the heart

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Internodal Pathways:

The following three internodal pathways connect the SA node and AV node:

i) The anterior internodal pathway or tract of Bachman,

ii) The middle internodal pathway or tract of Wenckebach, and

iii) The posterior internodal pathway or tract of Thorel.

Atrioventicular (AV) Node:

- It is located in the lower part of the right atrium, close to the inter-atrial septum, just above the atrioventricular ring.
- It is because the impulse formation is slower in AV node than that in the SA node.
- The pacemaker cells of AV node are suppressed by the SA nodal impulses.
- However, when SA node stops producing impulses, AV node becomes the pacemaker of the heart.
- Sometimes, it is also known as the pace-setter of heart as it controls the rate of impulse.

Bundle of His:

It is a small fibre bundle arising from the AV node and terminating in the Purkinje system.

This is located beneath the AV node and passes toward the inter-ventricular septum.

The bundle of His is nearly 1cm in length.

As it enters the inter-ventricular septum, it divides into the left bundle branch and the right bundle branch.

In case of non-functioning of SA node and AV node.

impulses are generated by the bundle of His.

Bundle Branches:

The branches of bundle fibres enter the walls of the ventricle to further branch out into very **small fibre bundles** in the inner walls of the muscles of the ventricle, which are termed as **Purkinje fibres**.

Bundle branches also have the ability to generate impulses. It is further divided into two branches:

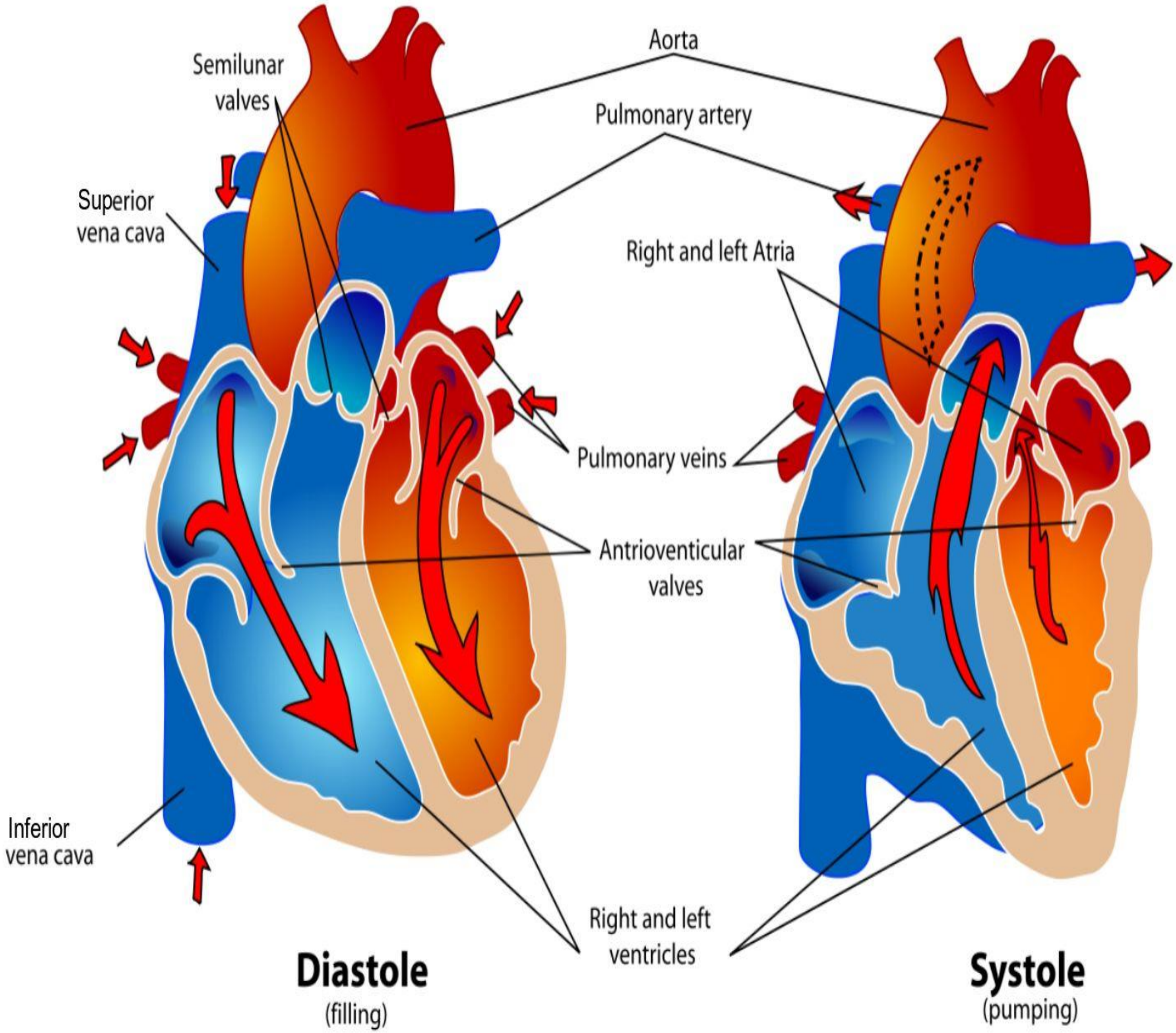
i) Right Bundle Branch: It supplies the right ventricle solely

ii) ii) Left Bundle Branch: It innervates the left ventricle.

Purkinje Fibres:

These fibres form a network of a small bundle of conducting fibres.

They are located all over the sub-endocardial regions of right and left ventricles.


Aorta
Semilunar valves
Pulmonary artery
Superior vena cava
Right and left Atria
Pulmonary veins
Antrioventicular valves
Inferior vena cava
Right and left ventricles
Diastole
(filling)
Systole
(pumping)

Cardiac cycle

The atria are continually filling with blood from the superior and inferior venae cavae (into the right atrium) and the pulmonary veins (into the left atrium).

Up to 70% of ventricular filling can be accomplished without any atrial contraction at all.

The SA node triggers a wave of contraction that spreads over the myocardium of both atria, emptying the atria and completing ventricular filling **(atrial systole 0.1 second**

When the electrical impulse reaches the AV node it is slowed down.

This results in a wave of contraction that sweeps upwards from the apex of the heart and across the walls of both ventricles pumping the blood into the pulmonary artery and the aorta **(ventricular systole 0.3 second;).**

The high pressure generated during ventricular contraction forces the atrioventricular valves to close, preventing backflow of blood into the atria.

Contraction of the ventricles is followed by complete cardiac diastole, a period of **0.4 second**, when atria and ventricles are relaxed.

During this time the myocardium recovers, ready for the next heartbeat, and the atria refill, ready for the next cycle

Stroke Volume

Stroke Volume (SV) is the volume of blood (in millilitres) pumped out from each ventricle due to the contraction of heart muscles, which compress these ventricles.

It is the difference between End Diastolic Volume (EDV) and End Systolic Volume (ESV). SV is influenced by the factors that alter either EDV or ESV.

Preload, afterload and contractility are the three primary factors that regulate SV.

SV is inversely affected by changes in Heart Rate (HR).

However, during exercise when other mechanisms are activated, SV can increase with an increase in HR; but if these mechanisms fail, SV cannot be maintained during an increased HR.

Stoke Volume Index

Stroke Volume Index (SVI) relates SV to Body Surface Area (BSA), thus relates an individual's heart performance to his/her size. The unit of measurement for SVI is millilitres per square metre (ml/m^2).

SVI = SV/BSA

Normal value of SV for a resting healthy individual is approximately 60- 100ml.

Patients who are undergoing surgery or are critically ill may require higher than normal SV and it may be more appropriate to aim for optimal rather than normal SV.

Cardiac output

Cardiac output is defined as the amount of blood flowing from the heart (i.e.. from the left ventricle into aorta) over a given period of time (or in one heartbeat).

OR

“Cardiac output refers to the volume of blood pumped out per ventricle per minute.”

Cardiac Output = Stroke Volume x Heart Rate

70ml x 72/min = 5040ml/min = nearly 5 litre/min

Blood Pressure

Blood pressure is **a measure of the force that your heart uses to pump blood around your body**. Normal blood pressure has high systolic value and low diastole value, i.e, 120mm Hg/80mm Hg in arteries. Arterial blood pressure may be of four types:

1) **Systolic Pressure**: It is the maximum pressure or peak pressure (120mmHg in a healthy adult) exerted in the arteries during the systole of the heart.

It occurs at the beginning of the cardiac cycle when the left ventricle contracts and pumps blood to the aorta.

2) Diastolic Pressure: It is the minimum pressure (80mmHg in a healthy adult) on the arteries. It occurs at the end of the cardiac cycle when the ventricles are in resting phase after pumping the blood.

3) Pulse Pressure: It is the differential pressure of systolic and diastolic pressure. It is about 40mmHg in a healthy adult.

4) Mean Arterial Pressure: It is the average pressure on the arteries.

Factors Influencing Blood Pressure

There are following factors affecting Blood pressure:

1) Age: Aging causes rise in blood pressure. The systolic blood pressure varies at different ages i.e., 70-90 mm of Hg in infants: 90-110 mm of Hg in child- hood; 110-120 mm of Hg at puberty; 140-150 mm of Hg at old age.

2) Sex: Both systolic and diastolic pressures are slightly lower in females as compared to males up to the age of 45-50 years.

3) Build: In most of the overweight persons the blood pressure is found to be high. The systolic pressure is usually high in obese person.

4) Exercise: In energetic exercise the systolic pressure increases and may reach even up to 180 mm of Hg whereas in moderate exercise there is slightly increase in systolic blood pressure.

5) Posture: While standing the diastolic pressure is slightly higher whereas in the leaning position the diastolic pressure is slightly lower than in the standing or in the sitting position.

6) Sleep: During sleep the systolic pressure decreases up to 15 to 20 mm of Hg.

7) After Ingestion of Meals: The systolic pressure rises after the metabolism of food.

8) Emotion of Excitement: It causes increase of systolic pressure.

CIRCULATION OF BLOOD THROUGH THE HEART

Introduction

With every heart beat the blood is pumped into two closed circuits, i.e., the pulmonary and the systemic circulation.

The arrangement of these two circuits is in the form of series, such that the output of blood from one system acts as the input for the other system.

While delivering oxygen and nutrients to the tissues, the cardiovascular system also carries away the waste materials eliminated from various organs like lungs, liver, and kidneys.

Systemic Circulation

1) Left side of the heart participates in systemic circulation and receives oxygenated blood from the lungs.

2) From the left ventricle blood is pumped into the aorta and the backflow is guarded by the aortic valve. Aorta divides into various systemic arteries which carry blood to all organs throughout the body, except the alveoli of the lungs.

The alveoli of the lungs are supplied by pulmonary circulation.

3) The arteries then divide into small diameter arterioles which further divide into systemic capillaries.

Nutrient and gaseous exchange are seen across the thin walls of the capillaries. Oxygen is delivered and carbon dioxide is picked up via capillaries.

4) The deoxygenated blood then enters the systemic venules (smallest diameter blood vessels carrying deoxygenated blood).

5) Next, via the systemic veins, blood enters the superior and inferior vena cava (the largest veins carrying deoxygenated blood from the upper and lower parts of the body, respectively to the heart) and the coronary sinus (receives deoxygenated blood of the heart) and brings back the deoxygenated blood to right atrium.

Pulmonary Circulation

1) The right side of the heart is involved in the pulmonary circulations.

It receives deoxygenated blood returning from the systemic circulation and pumped to the lungs.

2) The deoxygenated blood enters the right ventricle from the right atrium and the backflow is checked by the tricuspid valve.

3) The gaseous exchange takes place at the surface of alveoli and the blood gets oxygenated (i.e., loses carbon dioxide) in the pulmonary capillaries.

4) The oxygen-rich blood is then carried via pulmonary veins, to the left atrium from where it is distributed to the rest of the body systems.

Coronary Circulation

To work efficiently, the heart needs a continuous supply of oxygen and other nutrients along with a means for waste removal, just like other organ systems.

Therefore, the heart has its own system of circulation, i.e., coronary circulation, consisting of blood vessels that nourish all the cells of cardiac tissue:

1) The left and right coronary arteries originate at the base of the aorta, from where the coronary circulatory system begins.
2) From the base of the aorta, left and right coronary arteries originate and supply to the left and right side of the heart (atrium and ventricles), respectively.
3) The coronary arteries provide nutrient and oxygenated blood to cardiac cells At the same time, cardiac veins carry deoxygenated blood and metabolic waste, which further join into a single large vein, the coronary sinus.
4) The coronary sinus empties the deoxygenated blood into the right atrium.

PULSE/HEART RATE

Introduction

Pulse is defined as a wave of distension felt in the arteries with each heartbeat.

It is counted from radial artery of the wrist.

The pulse rate normally is the same as the heart rate.

Tachycardia is a rapid resting heart or pulse rate over 100 beats/min.

Bradycardia is a slow resting heart or pulse rate under 50 beats/min.

Normal Value of Heart Rate

Normal pulse rate ranges 70-90 per minute which may vary under the following conditions:

1) Pulse rate in man is 72/min and in woman 80/min.

2) Pulse rate in children is more rapid than an adult.

3) Pulse rate is increased under strong emotions, e.g., anger, excitement, etc.

4) Exercise increases the rate of pulse.

Variations in Heart Rate

Heart rate varies among individuals. It lowers when at rest and elevates during exercise.

Many individuals undergo minor changes in heart rate or rhythm, and thus no medical treatment is required if such individuals do not have other symptoms or a history of heart disease.

Causes

Pulse per minute is known as heart rate, which is increased by;

1) Increasing blood pressure in vena cava,
2) Increasing blood CO concentration,
3) Decreasing blood pH.
4) Increasing body temperature (core temperature)
5) Increasing hormone adrenaline.
6) **Coronary Heart Disease**: This heart problem is very serious and occurs when coronary arteries are blocked by cholesterol and other deposits.
7) **Medications**: Caffeine, amphetamines (drugs that stimulate the brain), and B-blockers (drugs that reduce high blood pressure) are the medications or substances that change the heart rate.

Symptoms

An individual having an abnormal heart rhythm may experience some or all of the following symptoms:

1) Faintness, dizziness, or light-headedness,
2) Breathlessness,
3) Irregular pulse or heart palpitations,
4) Chest pain,
5) Pale skin,
6) Sweating.

Factors Influencing Pulse

Following factors play a role in affecting the heart rate while running or walking:

1) **Emotions and Anxiety**: Heart rate increases if an individual is under stress or is in a state of anxiety.

2) **Body Temperature**: Body senses a thermal stress load if an becomes too hot or cold. Blood is sent to the skin to enhance heat dissipation to cool down the temperature or blood flow is increased to make the body warm.

3) **Terrain**: Walking or running uphill increases the heart rate. Walking or running downhill decreases the heart rate.

4) **Wind**: Walking or running with the wind at back is easy and decreases the heart rate. Walking or running into the wind is difficult and increases the heart rate.

CHANGES IN CARDIOVASCULAR SYSTEM

Cardiovascular Homeostasis in Exercise and Posture

Substantial changes in cardiovascular function are required to accommodate the physiological needs of intense physical exercise. This response aims to increase the cardiac output, selectively route that increased cardiac output.

Change in Heart Rate

Immediately after exercise, the heart is observed to be accelerated. It has been observed that the heart rate slightly increases even before the onset of exercise.

The heart rate slightly increases in the first minute of exercise; but, later this rate of increase is slightly decreased. Within 4-5 minutes of exercise, heart rate almost achieves the maximal rise.

Change in Cardiac Output

In response to anticipation and exercise, higher-order cerebral centres modulate the ANS to increase the cardiac output by increasing the SNS tone, which results in higher cardiac contractility, and thus heart rate.

Change in Venous Return

Venous return increases during exercise due to the following reasons:

1) Milking or Massaging Action of Skeletal Muscles: The muscles undergo alternate contraction and relaxation during the exercise, and this increases the blood flow towards the heart.

2) Respiratory Movements: These movements impose a sucking effect over the right heart and great veins to result in a greater venous return. During inspiration, the thoracic cavity becomes enlarged and reduces the intra thoracic pressure.

3) This decreased intra thoracic pressure and increased pressure on the anterior abdominal wall due to descent of diaphragm result in the rapid return of blood into the heart. Just the opposite effect is seen during expiration.

4) **Contraction of Limb Veins:** During exercise, limb veins undergo relax vasoconstriction and thus facilitate rapid venous return to the heart.