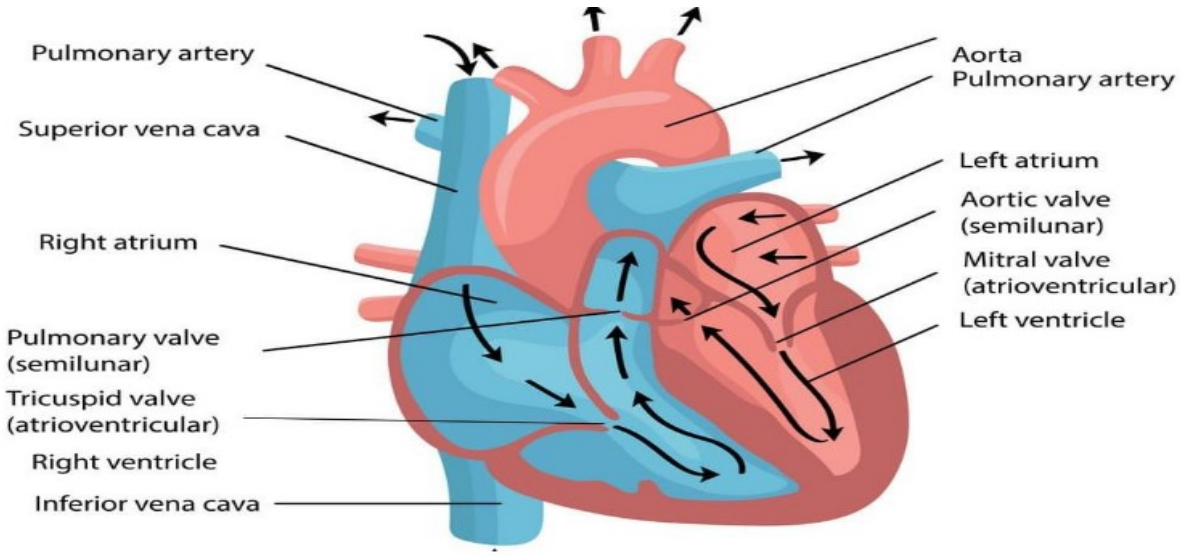
UNIT-V

CARDIOVASCULAR SYSTEM

The human cardiovascular system comprises of the heart, blood vessels and blood supply. The components of the cardiovascular system supply vital oxygen, nutrients and hormones to tissuesand remove carbon dioxide and metabolic waste products, It also plays an important role in stabilising body temperature and pH levels, as well as in maintains homeostasis.



Internal structure of heart

ANATOMY OF THE HEART

1. The heart is a small structure, roughly the same size as that of a person's closed fist.
2. Dimensions of heart is 12 cm long, 9 cm wide and 6 cm thick.
3. Average weight is 250 g in adult females and 300 g in adult males.
4. Position: It rests on the diaphragm, near the middle of thoracic cavity. It lies in the mediastinum that extends from the sternum to the vertebral column the first rib to the diaphragm and between the lungs. About two third of the heart lies to the left of the midline.
5. It consists of four chambers: two atria and two ventricles.

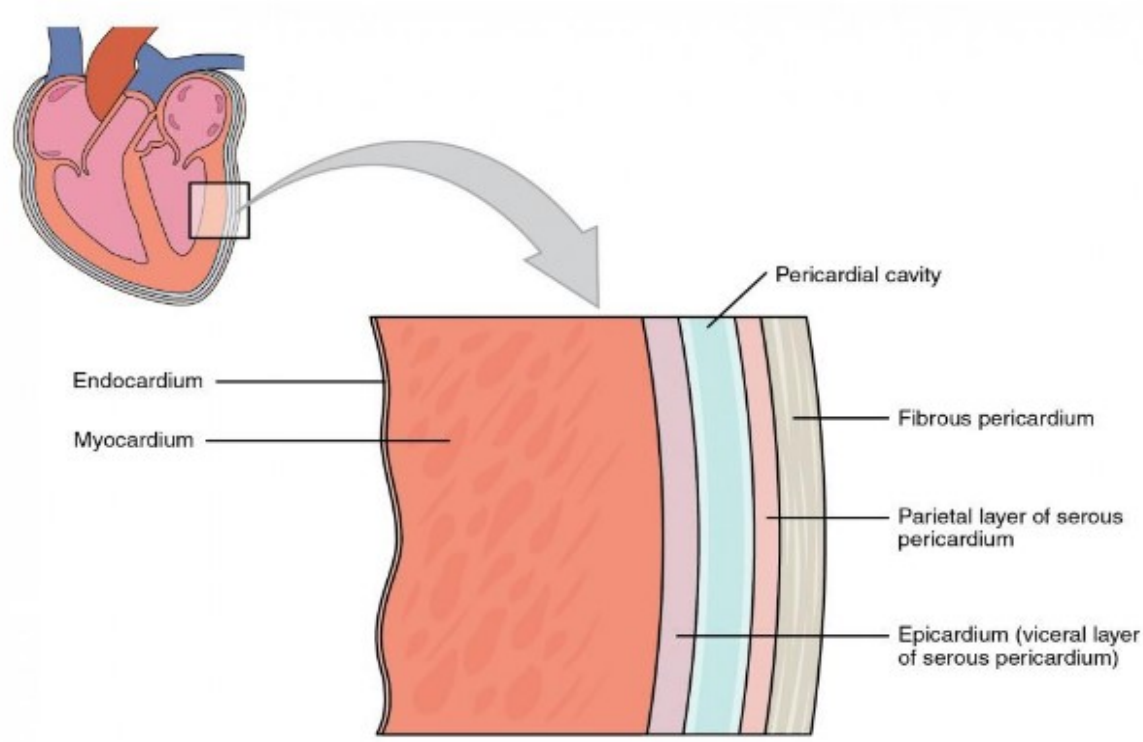
Structure of Pericardium and Heart Wall

The membrane that surrounds and protects the heart is the pericardium. It confines the heart to its position, while allowing sufficient freedom of movements for contraction. It consists of two main parts.

Fibrous Pericardium

It is composed of tough, inelastic, dense irregular connective tissue. The fibrous pericardium prevents overstretching of the heart, provides protection and holds the heart at particular position.

Serous Pericardium



Structure of pericardium

It is a thinner, more delicate membrane that forms a double layer around the heart. The outer parietal layer of serous pericardium also called as epicardium (external layer of heart wall). Thespace in between parietal and visceral layer is filled with pericardial fluid which is secreted by serous membrane itself. The space that contains the pericardial fluid called as pericardial cavity.

Heart Wall

The wall of heart consists of three layers.

1. **Epicardium (External layer):**
   It is the outermost, thin, transparent layer of heart wall is also called as visceral layer of the serous pericardium.
2. **Myocardium (Middle layer)**
   It is middle layer made up of cardiac muscle tissue. This middle layer makes up the bulk of the heart and is responsible for pumping action.
3. **Endocardium (Inner layer) :** It is the inner layer of myocardium. It consists of thin layer of endothelial cells. It provides smooth lining for the chambers of heart and covers the valves of the heart. The endocardium continues with the endothelial lining of the large blood vessels attached to the heart.

CHAMBERS OF THE HEART

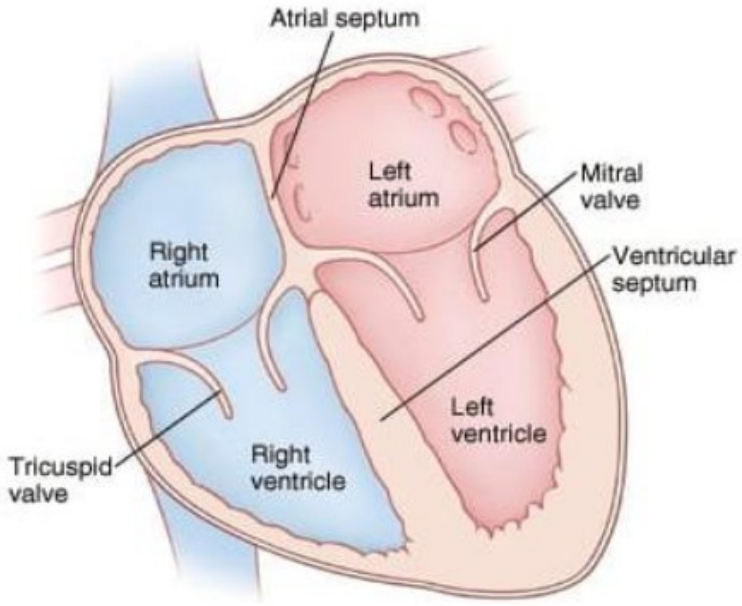
The heart has four chambers:

✓ **Two superior chambers :Right atrium and Left atrium**

✓ **Two inferior chambers: Right ventricle and Left ventricle**

Right Atrium

Externally, right atrium is roughly quadrangular in shape and can be divided into anterior part and posterior part. Superior vena cava present at the upper posterior part and inferior vena cavapresent at the lower posterior part. It has an appendage called auricle, which resembles a dog's ear.



Chambers of heart

Right Ventricle:

Externally, it is concave and forms a large part of heart. The wall of right ventricle varies greatly in thickness. It is much thinner than left ventricles. The wall of right ventricle is thickest at its atrial end and thinner towards the apex ventricle.

Left Atrium:

The wall of left atrium is thicker. It is smaller in shape than right atrium. It is roughly cuboidal inshape. The left auricle is longer, narrower and more curved than the right auricle. Four pulmonary veins open at the upper part of the left atrium. The auricle opens into the leftatrioventricular orifice guarded by bicuspid valve (mitral valve).

Left Ventricle:

It functions as a powerful pump operating at the highest pressure and hence the walls are threetimes thicker as that of right ventricle. It is cone shaped, longer and narrower than right ventricle.

VALVES OF THE HEART

A heart valve normally allows blood flow in only one direction through the heart. As each chamber of heart contracts, it pushes a portion of blood into a ventricle or out of the heart through an artery. To prevent back flow of blood, the heart has valves.

The four valves in the heart are

✓ The **two atrioventricular (AV) valves**, which are between the atria and the ventricles, are the mitral valve and the tricuspid valve.

✓ The **two semilunar (SL) valves,** which are in the arteries leaving the heart, are the aortic valve and the pulmonary valve.

Atrioventricular valves (AV valves)

These are small valves that prevent backflow of blood from the ventricles into the atrium during systole. It lies between the atria and ventricles. It is composed of two types of valves, the tricuspid and bicuspid or mitral valve.

Tricuspid Valve

The right AV valve between right atrium and right ventricle is called as tricuspid valve because it consists of three cusps (flaps).

✓ Septal valve

✓ Anterior cusp

✓ Posterior cusp

Bicuspid Valve

The left AV valve between left atrium and left ventricle is called as bicuspid valve because it consists of two cusps.It is also called as mitral valve. They open in one direction. Due to this arrangement, they prevent the back flow of blood from ventricles to the atria, during systole.

Semilunar Valves (SL. Valve)

These are located at the base of both the pulmonary trunk (pulmonary artery) and the aorta, the two arteries taking blood out of the ventricles. These valves permit blood to be forced into the arteries, but prevent backflow of blood from the arteries into the ventricles.

Aortic Semilunar Valve:

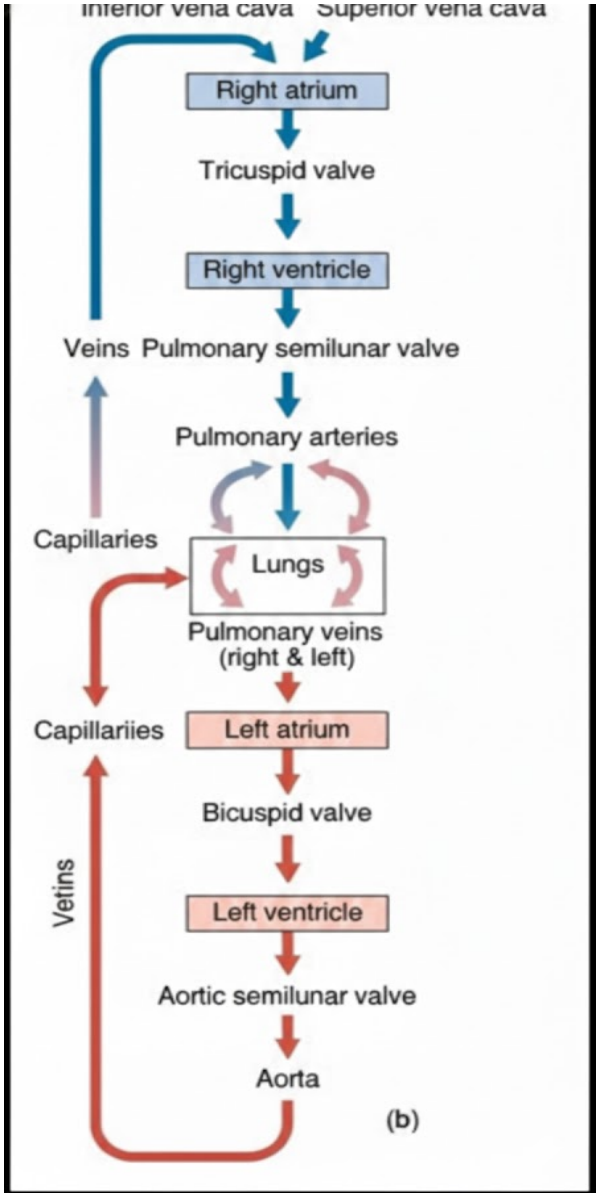
The aortic valve lies between the left ventricle and the aorta. It has three cusps. During ventricular systole, pressure rises in the left ventricle. When the pressure in the left ventricle rises above the pressure in the aorta, the aortic valve opens, allowing blood to exit the left ventricle into the aorta. When ventricular systole ends, pressure in the left ventricle rapidly drops. When the pressure in the left ventricle decreases, the aortic pressure forces the aortic valve to close.

BLOOD CIRCULATION

It is two types

1. Systemic and Pulmonary

2. Coronary circulation



1. Systemic and Pulmonary

The left side of the heart is the pump for systemic circulation. It receives bright red, oxygen-rich blood from the lungs. The left ventricle ejects blood into the aorta. From the aorta the blood divides into smaller systemic arteries.

2. Coronary Circulation

Coronary circulation refers to the movement of blood through the tissues of the heart. While the heart is contracting, little blood flows in the coronary arteries as squeezed shut. When the heart relaxes, the high pressure of blood in the aorta propels blood through the coronary arteries, into capillaries, and then into coronary veins.

Coronary Arteries

Two coronary arteries, the right and left coronary arteries, branch from the ascending aorta and supply oxygenated blood to the myocardium.

Coronary Veins

Most of the deoxygenated blood from the myocardium drains into a large vascular sinus in the coronary sulcus on the posterior surface of the heart, called the coronary sinus. The deoxygenated blood in the coronary sinus empties into the right atrium.

BLOOD VESSELS

The heart pumps blood into vessels that vary in structure, size and function.

Main types of blood vessels are

Arteries -> Arterioles -> Capillaries

Veins -> Venules-> Capillaries

Arteries

Arteries are the blood vessels that carry blood vessels away from the heart to other organs.

The wall of artery has three coats or tunics.

Tunica interna/intima:

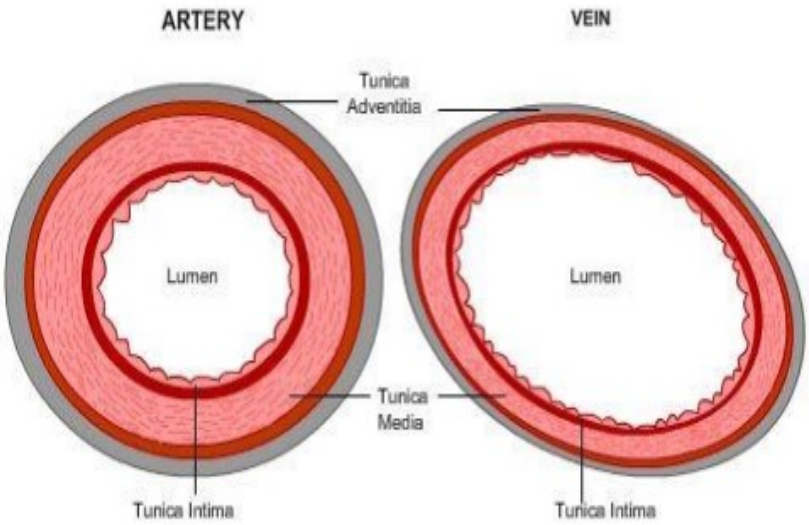
It contains a lining of simple squamous epithelium called as endothelium, a basement membrane.

Tunica media:

It is thickest layer and it consists of elastic fibres and smooth muscle fibres that extend circularly around the lumen like a ring.

Tunica externa: This outer layer or adventitia or outer layer made up of elastic and collagen fibres.

Arterioles



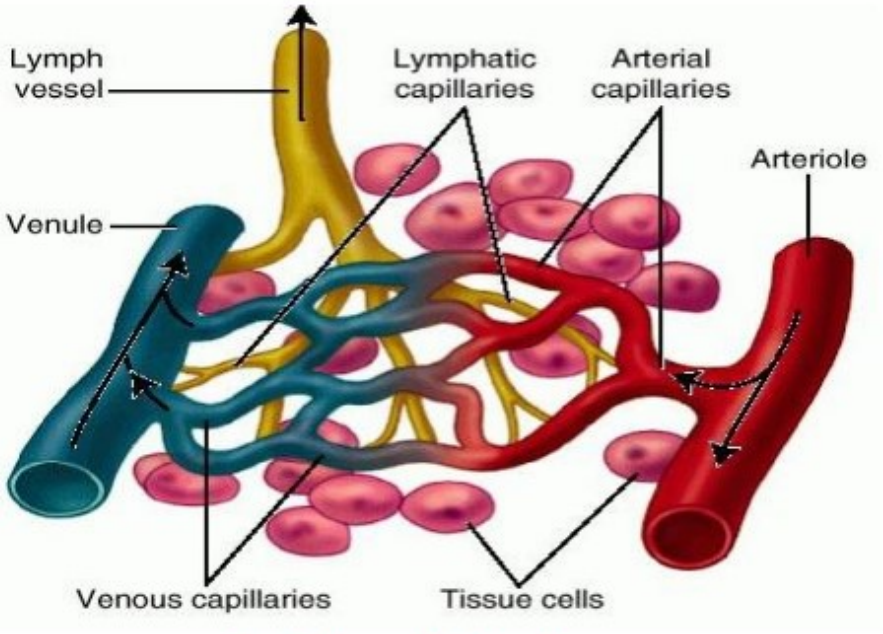
Structure of an artery and vein

Larger arteries leave the heart and divide into medium sized muscular arteries. Medium sized arteries then divide into small arteries which in turn divide into still smaller arteries called as

arterioles. An arteriole is very small ranging in diameter from 10 to 100 um. It delivers blood and regulates the flow of blood to capillaries.

Capillaries

The smallest arterioles break up into a number of minute vessels called as capillaries. These are microscopic vessels that connect arterioles to venules. Its diameter is 4 to 10 micro meters. The flow of blood from arterioles to venules through capillaries is called the microcirculation They are the sites of nutrients and waste exchange between the blood and body cells.



Arteriole, capillaries and venue

Veins

The veins are the blood vessels that convey blood from the tissues back to the heart. Its diameter ranges from 0.1 mm to greater than 1 mm. It consists of three coats as that of artery. They are thinner because there is less muscle and elastic tissue in tunica media. Veins carry blood at lower pressure than arteries.

Venules

The groups of capillaries within a tissue reunite to form small veins called as venules. The smallest veins are called as venules. The diameter is 10 to 100 micro meters. They collect blood from capillaries and deliver it to vein.

DIFFERENCE BETWEEN ARTERY AND VEIN

FEATURE	ARTERY	VEIN
Direction of Flow	Carries blood away from the heart.	Carries blood toward the heart.
Oxygen Content	Usually carries oxygenated blood (except Pulmonary Artery).	Usually carries deoxygenated blood (except Pulmonary Vein).
Blood Pressure	High pressure (pulses with heartbeats).	Low pressure (steady flow).
Wall Structure	Thick, elastic, and muscular walls.	Thin, less muscular walls.
Lumen (Internal Space)	Narrow lumen.	Wide lumen.
Valves	No valves (except at the base of the heart).	Contains valves to prevent backflow of blood.
Location	Deep-seated within the body.	Often closer to the skin surface.

CONDUCTING SYSTEM OF THE HEART

A special system is available in the heart which is responsible for the rhythmic contraction and conduction of impulses in the heart. The rate at which the heart conducts electrical impulses is called as the cardiac conduction.

This system can be divided into five parts.

✓ SA node or Sino atrial node

✓ AV node or Atrioventricular node

✓ AV bundle or bundle of His

✓ Right and left bundle branches

✓ Conduction myofibrils (Purkinje fibres)

SA Node

Cardiac excitation begins in the SA node, located in the right atrial wall just below the opening of superior vena cava. he action potential from the SA node propagates throughout both the atrium.

AV Node

The atrioventricular (AV) node lies on the right side of the partition that divides the atria, at the bottom of the right atrium. There is a brief delay when the impulses from the SA node reaches the AV node. During this period, the atria contract and empty their contents.

AV Bundle (Bundle of His)

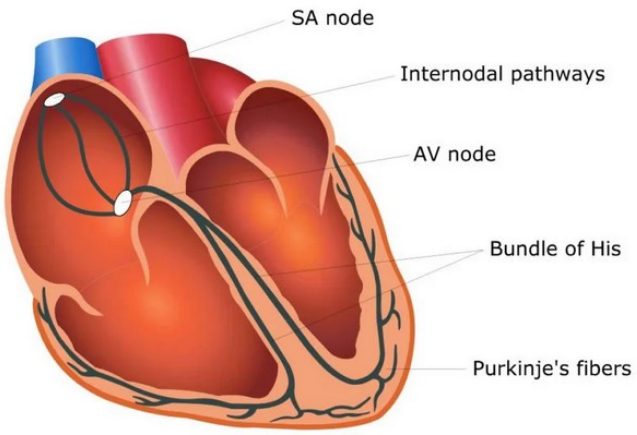
This bundle of fibres branches off into two bundles and the impulses are carried down the center of the heart to the left and right ventricles.

Right and Left Bundle Branches

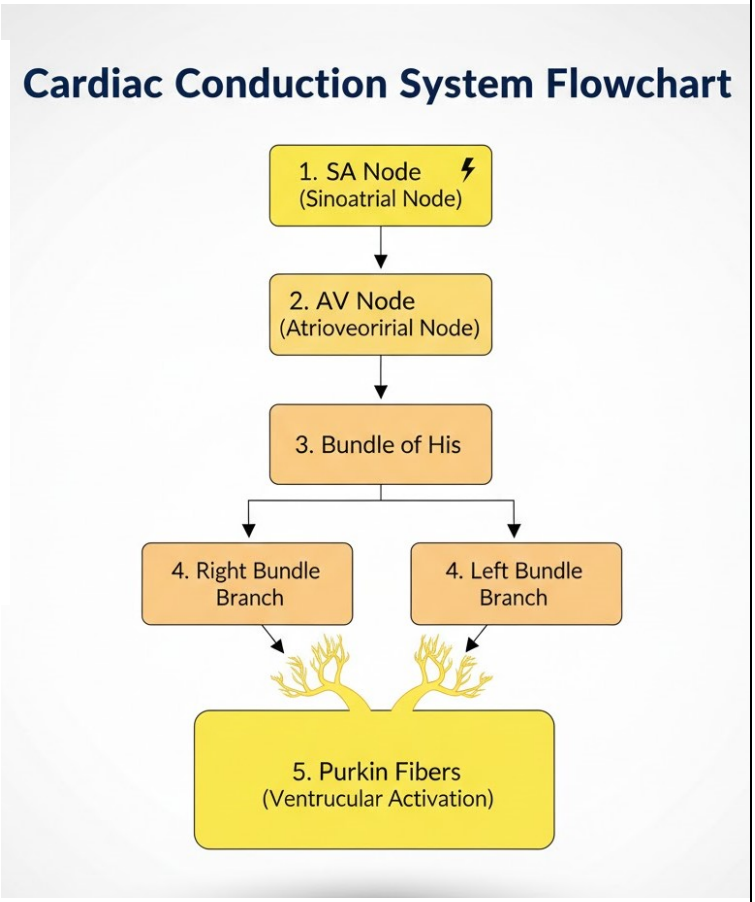
The bundle branches originate at the superior margin of the muscular interventricular septum, immediately below the membranous septum.After travelling along the AV bundle, the action potential then enters both the right and left bundle branches that runs through the interventricular septum towards the apex of the heart.

Purkinje Fibres

These fibres are less concentrated at the base of the ventricle and the papillary muscle tips. The Purkinje fibres connect with the ends of the bundle branches to form interweaving networks on the endocardial surface of both ventricles.



conduction system of heart in animals



REGULATIO OF HEART BEAT

The regulation of heartbeat is a fascinating balancing act managed by the **Autonomic Nervous System (ANS)**. While the heart has its own internal "pacemaker" (the SA node), the nervous system acts like a driver, constantly adjusting the speed and force based on body's needs.

This regulation happens primarily through a part of the brain called the **Medulla Oblongata**.

1. The Role of the Medulla Oblongata

The medulla contains the **cardiac center**, which receives sensory input about blood pressure and oxygen levels. It responds by sending signals through two different pathways:

a. The Sympathetic Nervous System (The Accelerator)

In the condition when stressed, exercising, or frightened, the sympathetic nervous system releases **Norepinephrine** which acts on the SA node to **increase heart rate** and increases the strength of the heart's contraction. This will help to pump more oxygenated blood to the muscles for a "fight or flight" response.

b. The Parasympathetic Nervous System (The Brake)

In the resting or eating condition, the parasympathetic nervous system takes over to conserve energy. The signals travel primarily via the **Vagus Nerve** (Cranial Nerve X). that releases

Acetylcholine neurotransmitter which acts on the SA node to decrease heart rate to maintain a steady "rest and digest" state.

CARDIAC OUTPUT

It is the volume of blood ejected from the left ventricle (or the right ventricle) into the aorta (or pulmonary trunk) each minute.

Cardiac output equals the stroke volume (SV), the volume of blood ejected by the ventricle during each contraction, multiplied by the heart rate (HR), the number of heart beats per minute:

CO = SV X HR

(mL/min.) (mL/beat) (beats/min.)

In a typical resting adult male, stroke volume averages 70 ml/beat, and heart rate is about 75 beats/min. Thus, average cardiac output is

CO = 70 mL/beat x 75 beats/min

= 5250 mL/min.

= 5.25 L/min.

This volume is close to the total blood volume, which is an about 5 liters in an adult male.

HEART SOUND

Auscultation is the act of listening to heart sounds with the help of stethoscope. The sound of heart beat comes primarily from blood turbulence caused by the closing of heart valves. During each cardiac cycle, there are four heart sounds, but in a normal heart only the first and second heart sounds (S1and S2) are loud enough to be heard through a stethoscope.

S1: It is caused by blood turbulence associated with closure of the AV valves soon after the ventricular systole begins. It is called as lubb sound, it is louder and longer than the second sound.

S2: It is caused by blood turbulence associated with closure of the semilunar valves at the beginning of ventricular diastole. It is called as dupp sound which is shorter than and not as loud as S1.

S3: It is a faint sound associated with blood turbulence during rapid ventricular filling.

S4: It is another faint sound caused due to blood turbulence during atrial systole

CARDIAC CYCLE

The sequence of events that occur from the beginning of one heart beat to the beginning of the next beat is known as the **cardiac cycle**.

The period of contraction that the heart undergoes while it pumps blood into circulation is called **systole** and the period of relaxation that occurs as the chambers fill with blood is called **diastole.** Both the atria and ventricles undergo systole and diastole, and their performance is carefully synchronised to ensure blood is pumped efficiently to the body.

PHASES OF CARDIAC CYCLE

Step 1: Atrial Systole (0.1 sec)

This is the "booster" phase. While most blood flows into the ventricles passively while the heart is at rest, this contraction tops them off.

- The SA node fires, the atria contract, and the remaining **20-30%** of blood is squeezed into the ventricles.
- **AV valves** (mitral/tricuspid) are open to allow flow, while the **Semilunar valves** are closed to prevent backflow from the arteries.
- The ventricles reach their maximum volume, known as **End-Diastolic Volume (EDV)**.

Step 2: Ventricular Systole (0.3 sec)

This is the "pumping" phase, divided into two distinct parts based on whether blood is actually moving yet.

a) Isovolumetric Contraction

As the ventricles begin to contract, pressure rises sharply. The pressure pushes the **AV valves** shut. This snap-shut creates the first heart sound (**S1** or "lub"). All valves are closed. The volume of blood doesn't change ("isovolumetric"), but the pressure is rising up to overcome the pressure in the aorta and pulmonary artery but no blood ejected out.

b) Ventricular Ejection

Once ventricular pressure exceeds the pressure in the arteries, the **Semilunar valves** (aortic and pulmonary) are forcefully opened. Blood is surged out into the body and lungs through aorta and pulmonary artery. The volume of blood pumped out per beat is called the **Stroke Volume**.

Step 3: Ventricular Diastole (0.4 sec)

This is the longest phase, dedicated to relaxation and refueling.

a) Isovolumetric Relaxation

- **The "Dub":** As the ventricles relax, pressure drops. Blood in the arteries tries to flow back toward the heart, which catches in the flaps of the **Semilunar valves**, snapping them shut. This creates the second heart sound (**S2** or "dup").

- **The Pause:** Briefly, all four valves are closed again as the ventricles continue to relax and pressure falls further.

b) Ventricular Filling

- **Refilling:** When ventricular pressure drops below atrial pressure, the **AV valves** pop open.
- **The Three Stages:**
    1. **Rapid Filling:** A gush of blood enters from the atria.
    2. **Diastasis (Reduced Filling):** Flow slows down as the pressures begin to equalize.
    3. **Completion:** The cycle resets to Step 1 (Atrial Systole) to complete the filling.

BLOOD PRESSURE

Blood pressure is lateral pressure excreted by blood on the vessels walls while flowing through it.

Systolic BP: It refers to phase of ventricular contraction.

Diastolic BP: It refers to phase of ventricles relaxation.

Normal = 120/80 mm Hg.

Pressure in blood vessels decreases as the distance from the heart increases.

It is essential to record both the diastolic and systolic BP because it gives information regarding status of working heart. BP varies from various physiological parameters like age, sex, exercise, posture, and sleep, emotions, etc.

Factors affecting on Blood Pressure

1. **Age:** Blood pressure increases as you get older.
2. **Gender:** Men tend to have higher blood pressure than women.
3. **Stress:** It can cause increased blood pressure.
4. **Diet:** Salt and saturated fats can increase blood pressure.
5. **Exercise**: Lack of physical activity increases blood pressure.

REGULATION OF BLOOD PRESSURE

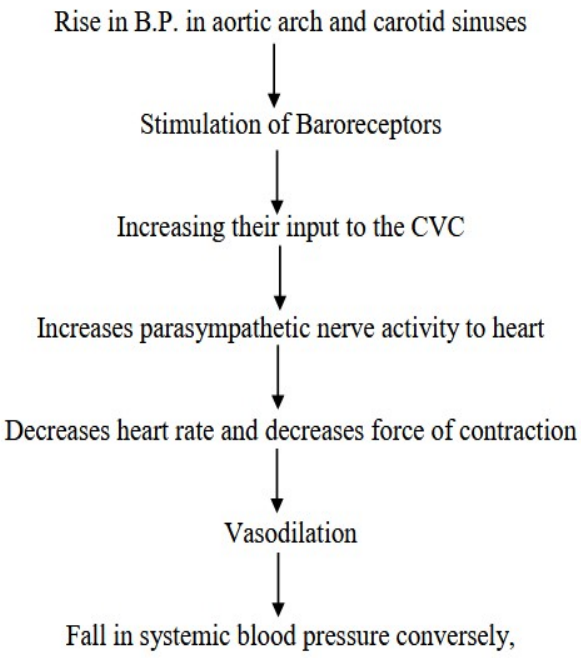
Neural Regulation of blood Pressure: The nervous system regulates blood pressure via two types of reflexes: baroreceptor reflexes and chemoreceptor reflexes. The cardiovascular center

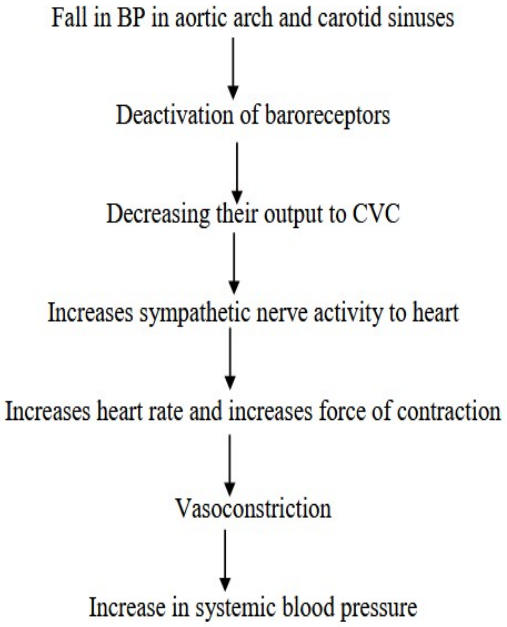
(CVC) is a collection of interconnected neurons in the brain and is situated within the medulla and pons. The CVC receives, integrates and co-ordinates inputs from:

1. Baroreceptors (pressure receptors)
2. Chemoreceptor
3. Higher centers in the brain.

Baroreceptors

Baroreceptors, pressure-sensitive sensory receptors, are located in the aorta, internal carotid arteries (arteries in the neck that supply blood to the brain), and other large arteries in the neck and chest. They send impulses to the cardiovascular center to help regulate blood pressure.

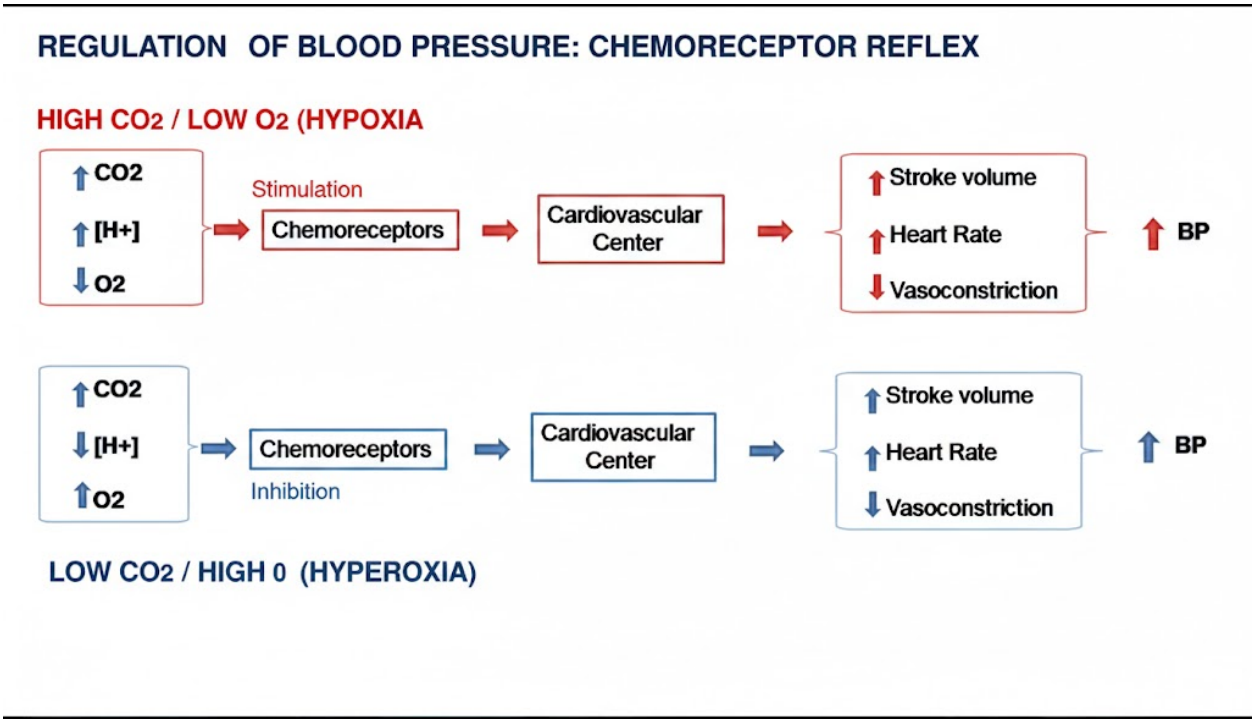




Baroreceptor control of blood pressure is called as Baroreceptor reflex.

Chemoreceptor

Chemoreceptors are sensory receptors that monitor the chemical composition of blood. These are located close to the baroreceptors. These chemoreceptors detect changes in blood level of O2, CO2, and H+. Hypoxia (lowered O2 availability), acidosis (an increase in H+ concentration), or hypercapnia (excess CO2) stimulates the chemoreceptors to send impulses to the cardiovascular center.



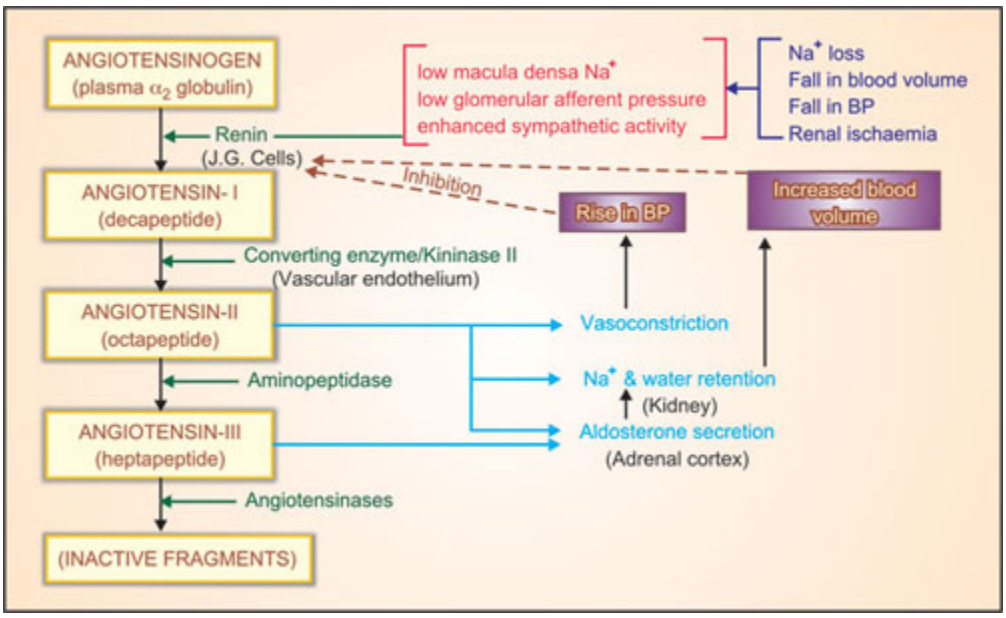
Hormonal Regulation of BP:

Epinephrine and Nor-epinephrine: In response to sympathetic stimulation, the adrenal medulla releases epinephrine and nor-epinephrine. These changes increases the cardiac output by increase in the heart rate and force of contraction.

Antidiuretic hormone (ADH): It is produced by hypothalamus and released from the posterior pituitary in response to dehydration or decrease in blood volume. ADH causes vasoconstriction which increases blood pressure. Hence, it is also called as vasopressin.

Atrial natriuretic peptide (ANP): It is released by the cells in the atria of the heart. ANP lowers blood pressure by causing vasodilation and by promoting the loss of salt and water in the urine which reduces blood volume.

RENIN-ANGIOTENSIN-ALDOSTERONE SYSTEM (RAAS)



Stimuli that initiate the renin-angiotensin-aldosterone pathway include dehydration, Na+ deficiency, or hemorrhage. These conditions cause a decrease in the blood volume.

↓

Decreased blood pressure

↓

Stimulates cells of the kidneys, called juxtaglomerular cells

↓

Secrete the enzyme rennin.

↓

Renin converts angiotensinogen and further Angiotensin I & Angiotensin II.

↓

Angiotensin II stimulates the adrenal cortex to secrete aldosterone.

↓

aldosterone increases the reabsorption of Na+ and water so that less is lost in the urine.

↓

Increased water reabsorption by the kidneys

↓

Blood volume increases

↓

Blood pressure increases to normal.

ELECTROCARDIOGRAM (ECG)

Conduction of action potential through heart generates electrical currents that can be detected at the surface of the body. A recording of the electrical changes that accompany each cardiac cycle is called as electrocardiogram. The instrument used to record the change is called as an electrocardiograph.

It consists of three waves

1. **P wave**
2. **QRS wave**
3. **T wave**

P Wave

It is small upward wave. It represents atrial depolarization which spreads from SA node throughout both atria.

QRS Wave

The complex represents three separate waves

1. **Q wave**
2. **R wave**
3. **S wave**

The complex begins with the downward deflection of Q wave, continues as a large, upright, triangular deflection of R wave and ends as a downward deflection of S wave. The QRS complex represents the ventricular depolarization.

T Wave

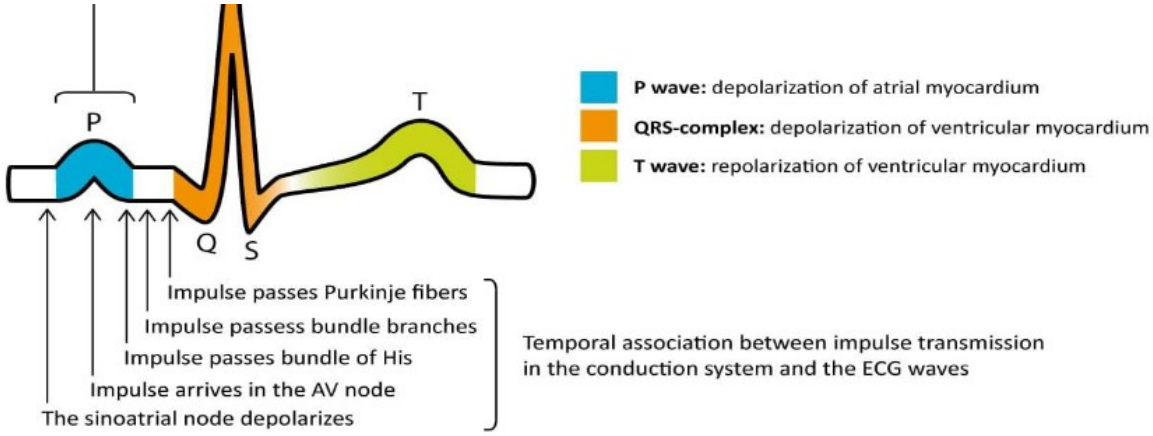
Third wave dome shaped upward deflection called as T wave. It represents ventricular repolarisation. The T wave is small and more spread out than the QRS complex because repolarisation occurs slower than the depolarization.

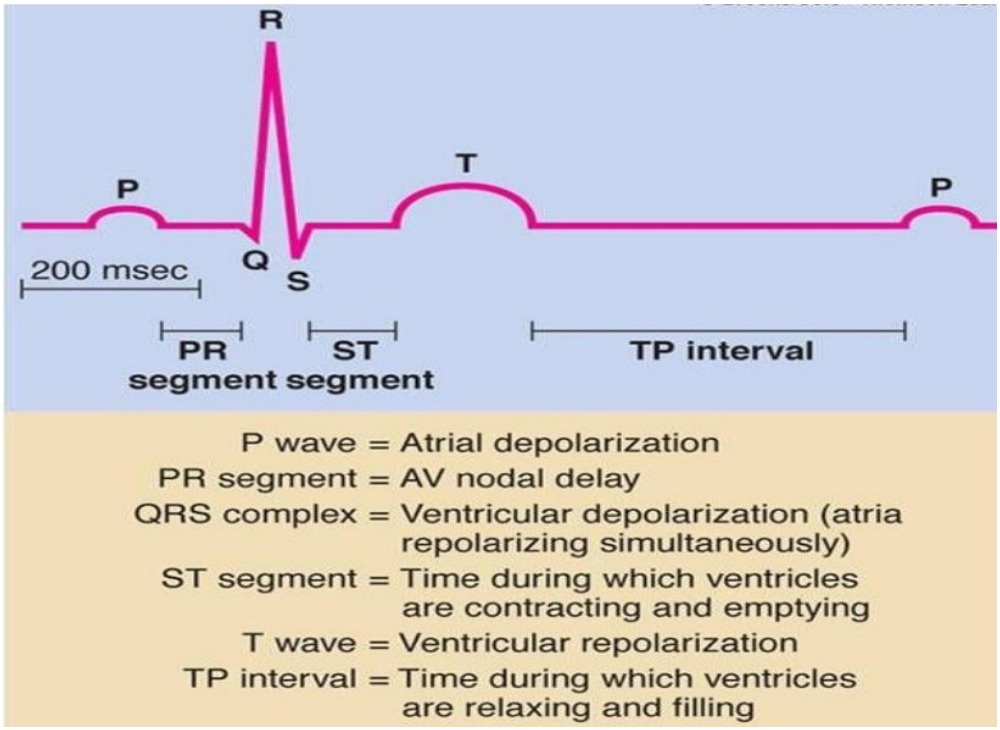
PQ or PR Interval

The duration between beginning of P wave and the beginning of QRS wave is called as PQ interval. It is also called as PR interval because the Q wave is frequently absent. It is interval between beginning of contraction of atria and beginning of contraction of ventricles.

QT Interval

The time from the beginning of S-wave and end of T-wave called as ST segment. ST wave segment represents ventricular contraction. During reading of an ECG, the size and timing of the waves is carefully noted. Following conclusions can be made with the altered ECG notes.


P
T
Q
S
P wave: depolarization of atrial myocardium
QRS-complex: depolarization of ventricular myocardium
T wave: repolarization of ventricular myocardium
Impulse passes Purkinje fibers
Impulse passess bundle branches
Impulse passes bundle of His
Impulse arrives in the AV node
The sinoatrial node depolarizes
Temporal association between impulse transmission
in the conduction system and the ECG waves


R
P
T
P
200 msec
Q
S
PR
segment
ST
segment
TP interval
P wave = Atrial depolarization
PR segment = AV nodal delay
QRS complex = Ventricular depolarization (atria repolarizing simultaneously)
ST segment = Time during which ventricles are contracting and emptying
T wave = Ventricular repolarization
TP interval = Time during which ventricles are relaxing and filling

DISORDERS OF HEART

Myocardial Ischemia

It is a condition of reduced blood flow to the myocardium caused by partial obstruction of blood flow in the coronary arteries (ische-_to obstruct; -emia_in the blood). Usually, ischemia causes hypoxia (reduced oxygen supply), which may weaken cells without killing them. Angina pectoris which literally means "strangled chest," is a severe pain that usually accompanies myocardial ischemia. The pain associated with angina pectoris is often referred to the neck, chin, or down the left arm to the elbow. Silent myocardial ischemia, ischemic episodes without pain, is particularly dangerous because the person has no forewarning of an impending heart attack.

Myocardial Infarction

A complete obstruction to blood flow in a coronary artery may result in a myocardial infarction or MI, commonly called a heart attack. Infarction means the death of an area of tissue because of interrupted blood supply. Because the heart tissue distal to the obstruction dies and is replaced by noncontractile scar tissue, the heart muscle loses some of its strength. Depending on the size and location of the infarcted (dead) area, an infarction may disrupt the conduction system of the heart and cause sudden death by triggering ventricular fibrillation.

Congestive Heart Failure (CHF)

There is a loss of pumping efficiency by the heart. Causes of CHF include coronary artery disease, congenital defects, long-term high blood pressure (which increases the afterload), myocardial infarctions (regions of dead heart tissue due to a previous heart attack), and valve disorders. As the pump becomes less effective, more blood remains in the ventricles at the end of each cycle, and gradually the end-diastolic volume (preload) increases.

Initially, increased preload may promote increased force of contraction (the Frank–Starling law of the heart), but as the preload increases further, the heart is overstretched and contracts less forcefully.

Coronary Artery Disease (CAD)

It results from the effects of the accumulation of atherosclerotic plaques in coronary arteries, which leads to a reduction in blood flow to the myocardium. Some individuals have no signs

or symptoms; others experience angina pectoris (chest pain), and still others suffer heart attacks. People who possess combinations of certain risk factors are more likely to develop CAD. Risk factors include smoking, high blood pressure, diabetes, high cholesterol levels, obesity, sedentary lifestyle, and a family history of CAD.

Atherosclerotic Plaques

Thickening of the walls of arteries and loss of elasticity are the main characteristics of a group of diseases called arteriosclerosis. One form of arteriosclerosis is atherosclerosis, a progressive disease characterized by the formation in the walls of large and medium-sized arteries of lesions called atherosclerotic plaques. It occurs due to deposition of low density lipoprotein in arteries.

Arrhythmias

The usual rhythm of heartbeats, established by the SA node, is called normal sinus rhythm. The term arrhythmia or dysrhythmia refers to an abnormal rhythm as a result of a defect in the conduction system of the heart. The heart may beat irregularly, too quickly, or too slowly. Symptoms include chest pain, shortness of breath, lightheadedness, dizziness, and fainting.

Arrhythmias may be caused by factors that stimulate the heart such as stress, caffeine, alcohol,

nicotine, cocaine, and certain drugs that contain caffeine or other stimulants. Arrhythmias may also be caused by a congenital defect, coronary artery disease, myocardial infarction, hypertension, defective heart valves, rheumatic heart disease, hyperthyroidism, and potassium deficiency.