The Cardiovascular System

The cardiovascular system consists of three components:
(1) the heart:
   which pumps blood so that it flows to tissue capillaries and lung capillaries
(2) the blood
(3) the blood vessels through which the blood flows.

The physiological and medical importance of the cardiovascular system has been apparent since William Harvey first described the circulation of blood in 1628. The system functions primarily to transport gases, nutrients, chemical messengers, heat, and immunologic elements toward target tissues and to remove from those tissues the chemical and thermal products of their metabolism. A secondary function is periodic engorgement of certain organs to the extent. The transport medium is blood, and it is pumped in a continuous circuit from the left heart, through the tissues, and back to the right heart.

THE HEART:

The heart is located in the thoracic cavity between the lungs. This area is called the mediastinum. It is a hollow, cone-shaped, muscular organ about the size of a fist. The base of the cone-shaped heart is uppermost, behind the sternum, and the great vessels enter or leave here. The apex (tip) of the heart points downward and is just above the diaphragm to the left of the midline. This is why we may think of the heart as being on the left side, because the strongest beat can be heard or felt here. The heart is enclosed in the pericardial membranes. As the heart pumps the blood through the pulmonary and systemic vessels, it performs these functions:
1. keeps O2-poor blood separate from O2-rich blood;
2. keeps the blood flowing in one direction—blood flows away from and then back to the heart in each circuit;
3. creates blood pressure, which moves the blood through the circuits;
4. regulates the blood supply based on the current needs of the body.
The Cardiac Muscle:

The heart is composed of three major types of cardiac muscle:
1- atria muscle  2- ventricular muscle
3- specialized excitatory and conductive muscle fibers.

Cardiac muscle is striated muscle, combines properties of both skeletal and smooth muscle, has typical myofibrils that contain actin and myosin filaments almost identical to those found in skeletal muscle; these filaments lie side by side and slide along one another during contraction, as the result of an arrangement of thick myosin and thin actin filaments similar to that of skeletal muscle.

cardiac muscle fibers are made up of many individual cells connected in series and in parallel with one another.
A mature cardiac muscle cell Myocytes is up to 100µ m long and 25µ m in diameter. Many have two nuclei, It contains numerous myofibrils, which are chains of sarcomeres, the fundamental contractile unit, Myocytes are coupled to one another by a net-like collagen matrix.
Adjacent cells are joined end to end at structures called intercalated disks, which are actually cell membranes that separate individual cardiac muscle cells from one another within which are desmosomes that hold the cells together and to which the myofibrils are attached.

Adjacent to the intercalated disks there are, permeable “communicating” junctions (gap junctions) that allow almost totally free diffusion of ions. Therefore, ions move with ease in the intracellular fluid along the longitudinal axes of the cardiac muscle fibers, so that action potentials travel easily from one cardiac muscle cell to the next, past the intercalated discs.

Thus, cardiac muscle is a syncytium of many heart muscle cells in which the cardiac cells are so interconnected that when one of these cells becomes excited, the action potential spreads to all of them, spreading from cell to cell throughout the interconnections.
The heart actually is composed of two syncytiums:
1- the atrial syncytium that constitutes the walls of the two atria,
2 - the ventricular syncytium that constitutes the walls of the two ventricles
Approximately 1 percent of the cardiac-muscle cells do not function in contraction, but have specialized features that are essential for normal heart excitation. These cells constitute a network known as the conducting system of the heart and are in contact with the other cardiac-muscle cells via gap junctions.
The conducting system initiates the heartbeat and helps spread the impulse rapidly throughout the heart. The atria are separated from the ventricles by fibrous tissue that surrounds the atrioventricular (A-V) valvular openings between the atria and ventricles. Normally, potentials are not conducted from the atrial syncytium into the ventricular syncytium directly through the fibrous tissue. Instead, they are conducted only by way of a specialized conductive system called the A-V bundle.

**Action Potential and Conducting System:**
Cardiac muscle has an intrinsic rhythmicity that allows the heartbeat to originate in and be conducted through the heart without extrinsic stimulation. The conduction system of the heart is a route of specialized cardiac muscle fibers that initiate and stimulate and coordinates contraction of the atria and ventricles, so that the heart is an effective pump. Without this conduction system, the atria and ventricles would contract at different rates. The conduction system enables the cardiac cycle, which refers to the events surrounding the filling and emptying of the chambers of the heart. The conduction system consists of specialized tissues (Nodal Tissue) that generate and distribute electrical impulses through the heart, which has both muscular and nervous characteristics. This unique type of cardiac muscle is located in two regions of the heart; its components are:

1. the sinoatrial node (SA node)
2. atrioventricular node (AV node)
3. atrioventricular bundle (bundle of His)
4. conduction myofibers (Purkinje fibers).

1. the sinoatrial node (SA node):
The SA node, or pacemaker, are a group of cells located in the posterior wall of the right atrium where the superior vena cava attaches to the heart. It is a specialized mass of cardiac muscle that depolarizes rhythmically and most rapidly, 60 to 80 times per minute and automatically sends out an excitation impulse every 0.85 second, and therefore initiates each heartbeat. For this reason it is sometimes called the pacemaker. The SA node initiates the cardiac cycle by the electrical impulse that spreads over both atria, causing them to contract simultaneously and force blood into the ventricles. The impulse then passes to the AV node.
2- atrioventricular node (AV node):
The AV node located in the lower interatrial septum, When the impulses reach the AV node, there is a slight delay that allows the atria to finish their contraction before the ventricles begin their contraction. The cells in the AV node generate an electrical impulse at a rate of 40-60 times per minute. The signal for the ventricles to contract travels from the AV node through the two branches of the atrioventricular bundle (AV bundle).

3- atrioventricular bundle (bundle of His):
(AV bundle), also called the bundle of His, it is within the upper interventricular septum, it receives impulses from the AV node and transmits them to the right and left bundle branches which are continuous with the conduction myofibers within the ventricular walls. Stimulation of these fibers causes the ventricles to contract simultaneously. From the bundle branches, impulses travel along Purkinje fibers.

The conduction system also innervated by the autonomic nervous system in order to respond to the ever-changing physiological needs of the body. The SA and AV nodes have both sympathetic and parasympathetic innervation. Sympathetic stimulation accelerates the heart rate and dilates the coronary arteries, enabling the heart to meet its own increased metabolic demands as well as those of the rest of the body. Parasympathetic stimulation has the opposite effect. Sympathetic innervation is through fibers from the cervical and upper thoracic ganglia. Parasympathetic innervation is through branches of the vagus nerves. Branches from the right vagus innervate the SA node, and branches from the left vagus innervate the AV node.

**Electrocardiogram**
A graph that records the electrical activity of the myocardium during a cardiac cycle (heartbeat). The electrical impulses that pass through the conduction system of the heart during the cardiac cycle or is called an electrocardiogram, or ECG. The electrical changes result from depolarization and repolarization of cardiac muscle fibers and can be detected on the surface of the skin using an instrument called the electrocardiograph.

ECG is obtained by placing on the patient’s skin several electrodes that are wired to a voltmeter (an instrument for measuring voltage). As the heart’s chambers contract and then relax, the change in polarity is measured in mill volts. A typical ECG consists of three distinguishable waves or deflections: the P wave, the QRS complex, and the T wave. Each produced as specific events of the cardiac cycle occur.
Any heart disease that disturbs the electrical activity will produce characteristic changes in one or more of these waves, so understanding the normal wave-deflection patterns is clinically important.

The P Wave:
Depolarization of the atrial fibers of the SA node (the transmission of electrical impulses from the SA node throughout the atrial myocardium) produces the P wave. The actual contraction of the atria follows the P wave by a fraction of a second. The ventricles of the heart are in diastole during the expression of the P wave. A missing or abnormal P wave may indicate a dysfunction of the SA node.

QRS Complex:
The QRS complex begins as a short downward deflection (Q), continues as a sharp upward spike (R), and ends as a downward deflection (S). The QRS complex indicates the depolarization of the ventricles as the electrical impulses spread throughout the ventricular myocardium following excitation of the Purkinje fibers. It signals that the ventricles are going to be in systole and that the ventricular myocardium is about to contract. The QRS complex shows greater voltage changes than the P wave because the ventricles have more muscle mass than the atria. During this interval, the ventricles are in systole and blood is being ejected from the heart. It is also during this interval that the atria repolarize, but this event is obscured by the greater depolarization occurring in the ventricles. An abnormal QRS complex generally indicates cardiac problems of the ventricles. An enlarged R spike, for example, generally indicates enlarged ventricles.

The T wave:
represents repolarization of the ventricles. It signals that the ventricles are going to be in diastole and that the ventricular myocardium is about to relax. An arteriosclerotic heart will produce altered T waves, as will various other heart diseases.

The P-R Interval:
On the ECG recording, the P-R interval is the period of time from the start of the P wave to the beginning of the QRS complex. This interval indicates the amount of time required for the SA depolarization to reach the ventricles. A prolonged P-R interval suggests a conduction problem at or below the AV node.
S-T Segment :-
The time duration known as the S-T segment represents the period between
the completion of ventricular depolarization and initiation of repolarization.
The S-T segment is depressed when the heart receives insufficient oxygen; in
acute myocardial infarction, it is elevated.

The CARDIAC CYCLE

The cardiac cycle is the sequence of events in one heartbeat, it is a sequence of
events that keeps blood moving from the veins, through the heart, and into the
arteries.
Each cycle is initiated by spontaneous generation of an action potential in the
sinus node.
The cardiac cycle consists of a period of relaxation called diastole, during
which the heart fills with blood, followed by a period of contraction called
systole.
the simultaneous contraction of the two atria, followed a fraction of a second
later by the simultaneous contraction of the two ventricles, there are three
phases of the cardiac cycle including:

Phase 1: Atrial Systole (Time _ 0.15 sec) :-
During this phase, both atria are in systole (contracted), while the ventricles
are in diastole (relaxed).
Rising blood pressure in the atria forces open the right and left AV valves, so,
the blood enters the two ventricles through the AV valves. At this time, both
atrioventricular valves are open, and the semilunar valves are closed.

Phase 2: Ventricular Systole (Time _ 0.30 sec) :-
During this phase, both ventricles are in systole (contracted), while the atria
are in diastole (relaxed). Rising blood pressure in the contraction ventricles
forces blood against the flaps of the right and left AV valves and closes them;
the force of blood also opens the aortic and pulmonary semilunar valves.
As the ventricles continue to contract, they pump blood into the arteries.
forces the blood to enter the pulmonary trunk leading to the pulmonary
arteries and aorta through the semilunar valves. At this time, both semilunar
valves are open, and the atriocentricular valves are closed.

Phase 3: Atrial and Ventricular Diastole (Time _ 0.40 sec):-
During this period, both atria and both ventricles are in diastole (relaxed). At
this point, pressure in all the heart chambers is low. Blood returning to the
heart from the superior and inferior venae cavae and the pulmonary veins
fills the right and left atria and flows passively into the ventricles. At this time, both atrioventricular valves are open, and the semilunar valves are closed.

The HEART SOUNDS

The cardiac cycle also creates the heart sounds: A heartbeat produces the familiar “LUB-DUP” sounds as the chambers contract and the valves close. The first heart sound, “lub,” is heard when the ventricles contract and the atrioventricular valves close. This sound lasts longest and has a lower pitch. The second heart sound, “dup,” is heard when the relaxation of the ventricles allows the aortic and pulmonary semilunar valves to close. If any of the valves do not close properly, an extra sound called a heart murmur may be heard, a physician listening for heart sounds will place a stethoscope at locations designated