CARDIOVASCULAR SYSTEM

Introduction

The main function of the *circulatory system*, which consists of the heart and blood vessels, is transport. The circulatory system delivers oxygen and nutrients needed for metabolic processes to the tissues, carries waste products from cellular metabolism to the kidneys and other excretory organs for elimination, and circulates electrolytes and hormones needed to regulate body function.

The heart, shown in **Figure 1-1**, is actually two separate pumps: a *right heart* that pumps blood through the lungs, and a *left heart* that pumps blood through the systemic circulation that provides blood flow to the other organs and tissues of the body. In turn, each of these hearts is a pulsatile two-chamber pump composed of an *atrium* and a *ventricle.* Each atrium is a weak primer pump for the ventricle, helping to move blood into the ventricle. The ventricles then supply the main pumping force that propels the blood either (1) through the pulmonary circulation by the right ventricle or (2) through the systemic circulation by the left ventricle.

Special mechanisms in the heart cause a continuing succession of heart contractions called *cardiac rhythmicity*, transmitting action potentials throughout the cardiac muscle to cause the heart's rhythmical beat. This rhythmical control system is explained in Chapter 10. In this chapter, we explain how the heart operates as a pump, beginning with the special features of cardiac

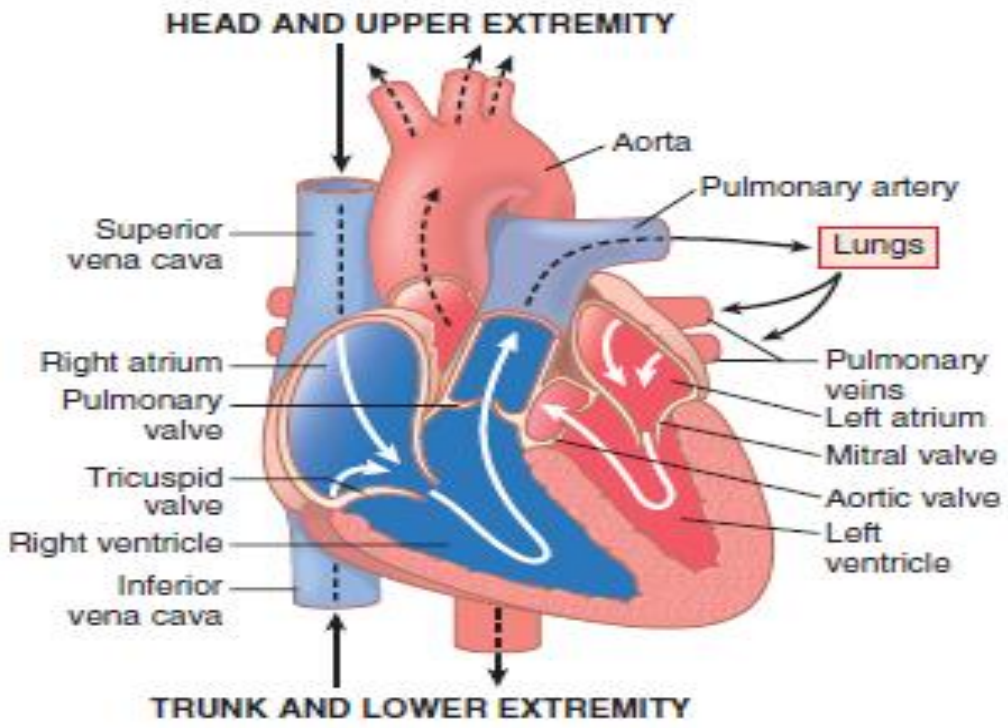


Figure ,1-1 :structure of the heart and course of blood flow through the heart chambers and heart valves.

It situated between the two lungs in mediastinum. Its rests on the muscular diaphragm, 2/3 of heart is to the left and 1/3 to the right of midline. It has a base, apex and three surfaces: anterior, posterior and inferior surfaces.
The apex of the heart is directed interiorly, inferiorly and to the left. The base is directed posteriorly, superiorly and to right. Its roughly the size of a clenched fist and weight about 300-330 g. The musculature of ventricles is thicker than atria. Force of contraction of heart depends upon the muscles.

Right side of the heart

Right side of the heart has two chambers, right atrium and right ventricle. Right atrium is a thin walled and low pressure chamber. It has got the pacemaker known as sinoatrial node that produces cardiac impulses and atrioventricular node that conducts the impulses to the ventricles. Right atrium receives venous (deoxygenated) blood via two large veins:

1. Superior vena cava that returns venous blood from the head, neck and upper limbs

2. **Inferior vena cava** that returns venous blood from lower parts of the body. Right atrium communicates with right ventricle through tricuspid valve. Wall of right ventricle is thick. Venous blood from the right atrium enters the right ventricle through this valve. From the right ventricle, pulmonary artery arises. It carries the venous blood from right ventricle to lungs. In the lungs, the deoxygenated blood is oxygenated.

3.Coronary sinus, coronary arteries branch from the base of ascending aorta and perfuse the heart wall.

Left side of the heart

Left side of the heart has two chambers, left atrium and left ventricle. Left atrium is a thin walled and low pressure chamber. It receives oxygenated blood from the lungs through pulmonary veins.
This is the only exception in the body, where an artery carries venous blood and vein carries the arterial blood. Blood from left atrium enters the left ventricle through mitral valve (bicuspid valve). Wall of the left ventricle is very thick. Left ventricle pumps the arterial blood to different parts of the body through systemic aorta.

Covering of heart

Heart is enveloped in a fibroserous covering called pericardium. It is a two layered structure, outer layer being the fibrous pericardium and the inner double layered covering called the serous pericardium. The outer layer of serous pericardium is called parietal layer and inner is visceral layer of serous pericardium.

Between these layers is a potential space called pericardium cavity which contains about 5-15 mL of pericardial fluid. The apex of the pericardium. It is connected to central tendon of diaphragm. Pericarditis infection or inflammation of pericardium is pericarditis. The inflamed pericardial surfaces may rub against each other during cardiac contraction producing a sound called pericardial rub which can be heard as a rubbing sound by auscultation

Pulmonary and Systemic Circulations

The circulatory system can be divided into two parts: the *pulmonary circulation*, which moves blood through the lungs and creates a link with the gas exchange function of the respiratory system, and the *systemic circulation,*which moves blood throughout all the other tissues of the body.

The pulmonary circulation consists of the right side of the heart, the pulmonary arteries, the pulmonary capillaries, and the pulmonary veins. The large pulmonary vessels are unique in that the pulmonary artery is the only artery that carries deoxygenated venous blood and the pulmonary veins are the only veins that carry oxygenated arterial blood. The systemic circulation consists of the left side of the heart, the aorta and its branches, the capillaries that supply the brain and peripheral tissues, and the systemic venous system and the vena cava.

The veins from the lower portion of the body merge to form the inferior vena cava and those from the head and upper extremities merge to form the superior vena cava, both of which empty into the right heart.

Although the pulmonary and systemic circulations function similarly, they have some important differences.

The pulmonary circulation is the smaller of the two and functions with a much lower pressure. Because the pulmonary circulation is located in the chest near the heart, it functions as a low-pressure system with a mean arterial pressure of approximately 12 mm Hg. The low pressure of the pulmonary circulation allows blood to move through the lungs more slowly, which is important for gas exchange. Because the systemic circulation must transport blood to distant parts of the body, often against the effects of gravity, it functions as a high-pressure system, with a mean arterial pressure of 90 to 100 mm Hg.

Both sides of the heart are further divided into two chambers, an *atrium* and a *ventricle*.

The atria function as collection chambers for blood returning to the heart and as auxiliary pumps that assist in filling the ventricles. The ventricles are the main pumping chambers of the heart. The right ventricle pumps blood through the pulmonary artery to the lungs and the left ventricle pumps blood through the aorta into the systemic circulation. The ventricular chambers of the right and left heart have inlet valves and outlet valves that act reciprocally (i.e., one set of valves is open while the other is closed) to control the direction of blood flow through the cardiac chambers and into the arteries.

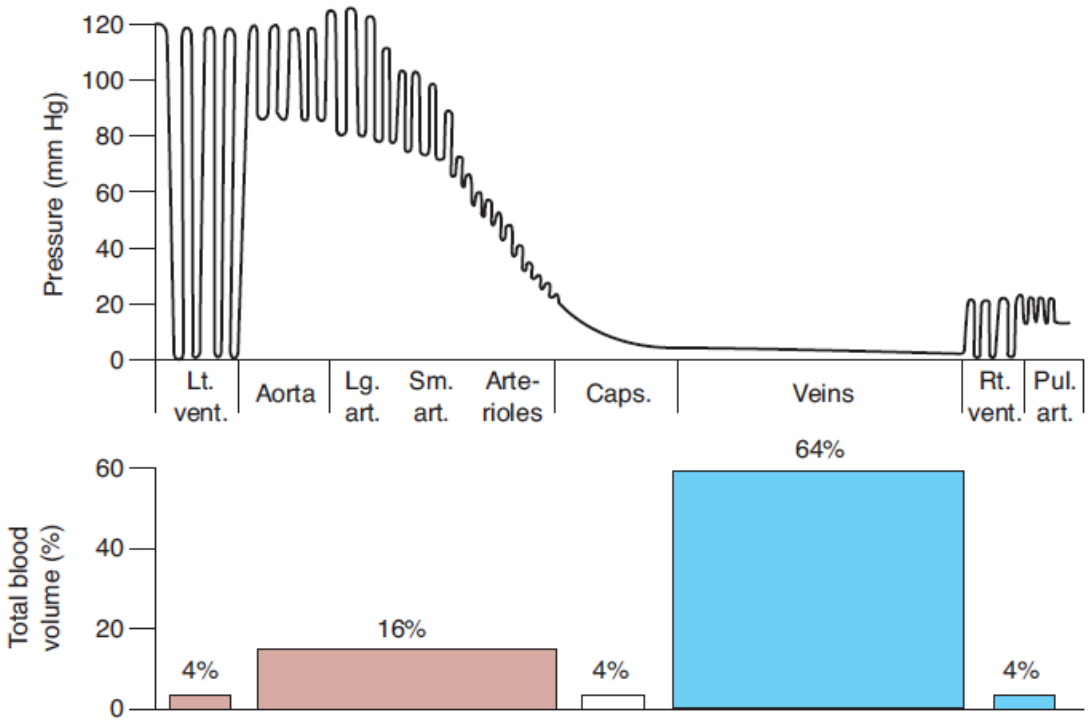
Volume and Pressure Distribution

Blood flow in the circulatory system depends on a blood volume that is sufficient to fill the blood vessels and a pressure difference across the system that provides the force that is needed to move blood forward. Approximately 4% of the blood at any given time is in the left heart, 16% is in the arteries and arterioles, 4% is in the capillaries, 64% is in the venules and veins, and 4% is in the right heart.

The arteries and arterioles, which have thick, elastic walls and function as a distribution system, have the highest pressure. The capillaries are small, thin-walled vessels that link the arterial and venous sides of the circulation. They serve as an exchange system where transfer of gases, nutrients, and wastes take place. Because of their small size and large surface area, the capillaries contain the smallest amount of blood. The venules and veins, which contain the largest amount of blood, are thin-walled, distensible vessels that function as a reservoir to collect blood from the capillaries and return it to the right heart.

Blood moves from the arterial to the venous side of the circulation along a pressure gradient, moving from an area of higher pressure to one of lower pressure. The pressure distribution in the different parts of the circulation is almost an inverse of the volume distribution The pressure in the arterial side of the circulation,which contains only approximately one sixth of the blood volume, is much greater than the pressure

on the venous side of the circulation, which contains approximately two thirds of the blood. This pressure and volume distribution is due in large part to the structure and relative elasticity of the arteries and veins. It is the pressure difference between the arterial and venous sides of the circulation (approximately 84 mm Hg) that provides the driving force for flow of blood in the systemic circulation.The pulmonary circulation has a similar arterial–venous pressure difference, albeit of a lesser magnitude, that facilitates blood flow.



Figure,2-1:Pressure and volume distribution in the systemic circulation. The graphs show the inverse relation between internal pressure and volume in different portions of the circulatory system.

Principles of blood flow

The term *hemodynamics* refers to the principles that govern blood flow in the circulatory system. The term hemodynamics is used to describe factors such as (1) pressure and resistance, (2) vessel radius, (3) cross-sectional area and velocity of flow, and (4) laminar versus turbulent flow that affect blood flow through the blood vessels in the body

Pressure, Resistance, and Flow

The most important factors governing the flow of blood in the circulatory system are *pressure, resistance,* and *flow.* Blood flow, which is determined by the pressure difference (ΔP) between the two ends of a vessel or group of vessels and the resistance (R) that blood must overcome as it moves through the vessel or vessels, can be expressed by the equation flow = ΔP /R.

In the circulatory system, blood flow is represented by the cardiac output (CO).

Resistance is the opposition to flow caused by friction between the moving blood components and the stationary vessel wall. In the peripheral circulation, the collective resistance of all the vessels in that part of the circulation is referred to as the *peripheral vascular resistance* (PVR) or, sometimes, as the *systemic vascular resistance.* The red blood cells, which constitute 40% to 45% of the formed elements of the blood, largely determine the viscosity of the blood.