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L3 Physics of the cardiovascular system

The cells of the body act like individual engines. In order for them to function, they must have: -

1. Fuel from our food to supply energy.
2. O2 from the air we breathe to combine with the food to release energy.
3. A way to dispose of the by-products of the combustion (mostly CO2, H2O, and heat).

Since the body has many billions of cells, an elaborate transportation system is need to deliver the fuel and O2 to the cells and remove the by-products. The blood performs this important body function.

The blood pumped by contraction of the heart muscle, from left ventricle at pressure of 125 mmHg and finally into very fine meshwork or capillary bed for few seconds the blood supplies O_2 to cells and picks up CO_2. Adult has about 4.5 liters of blood, each section of heart pumps 80 ml with each contraction.

Blood represents about 7% of the body mass or about 4.5kg (~4.4 liters) in a 64kg person. The combination of RBC and plasma causes blood to have flow properties different from those of fluid like water.

The cardiovascular system (CVS).

The cardiovascular system consists of the heart, blood vessels, and the approximately 5 liters of blood that the blood vessels transport.

The Heart as main components of the cardiovascular system

The cardiovascular system powered by the body's hardest-working organ the heart, which is only about the size of a closed fist. Even at rest, the average heart easily pumps over 5 liters of blood throughout the body every minute.

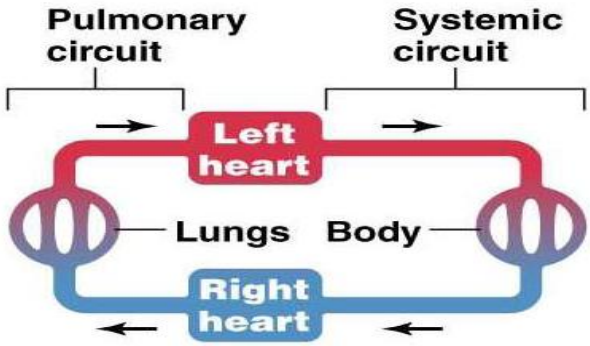
This system has three main functions:

1. ***Transport*** **of nutrients, oxygen, and hormones to cells throughout the body and removal of metabolic wastes (carbon dioxide, nitrogenous wastes).**
2. ***Protection*** **of the body by white blood cells, antibodies, and complement proteins that circulate in the blood and defend the body against foreign microbes and toxins. Clotting mechanisms are also present that protect the body from blood loss after injuries.**
3. ***Regulation*** **of body temperature, fluid pH, and water content of cells.**

Major components of the cardiovascular system

The heart is basically a double pump; it provides the force needed to circulate the blood through the two major circulatory systems: -

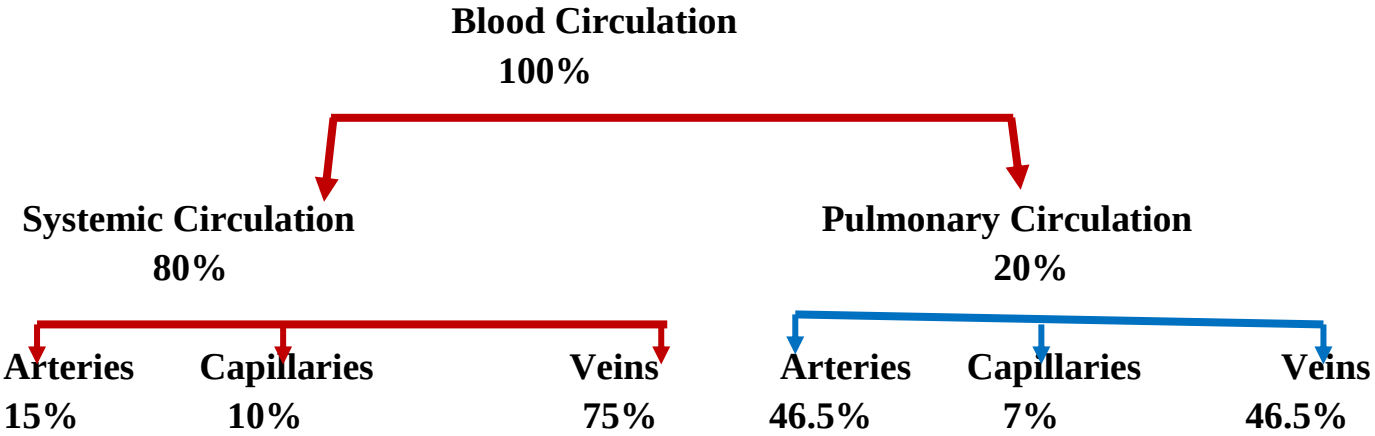
1. **Pulmonary circulation in the lungs. Transports deoxygenated blood from the right side of the heart to the lungs, where the blood picks up oxygen and returns to the left side of the heart. The pumping chambers of the heart that support the pulmonary circulation loop are the right atrium and right ventricle.**



2. **Systemic circulation in the rest of the body: carries highly oxygenated blood from the left side of the heart to all of the tissues of the body (with the exception of the heart and lungs). Systemic circulation removes wastes from body tissues and returns deoxygenated blood to the right side of the heart. The left atrium and left ventricle of the heart are the pumping chambers for the systemic circulation loop.**

The heart has a system of valves that, if functioning properly, permit the blood to flow only in the correct direction. If these valves become diseased and do not open or close, properly the pumping of the blood becomes inefficient.

The blood volume is not uniformly divided between the pulmonary and systemic circulation, but it is:



Example: calculate the mass of the blood in all circulation of a person his body mass is 80Kg?

Mass of Blood 80x7/100 = 5.6kg					
Mass of Blood in Systemic Circulation 5.6x80/100 = 4.48kg			Mass of Blood in Pulmonary Circulation 5.6x20/100 = 1.12kg		
Arteries 4.48x15/100 = 0.672kg	Capillaries 4.48x10/100 = 0.448kg	Veins 4.48x75/100 = 3.360kg	Arteries 1.12x46.5/100 = 0.521kg	Capillaries 1.12x7/100 = 0.078kg	Veins 1.12x46.5/100 = 0.521kg

H.W : The mass of the pulmonary blood of a person is 1.5kg, find:

1) The mass of this person?

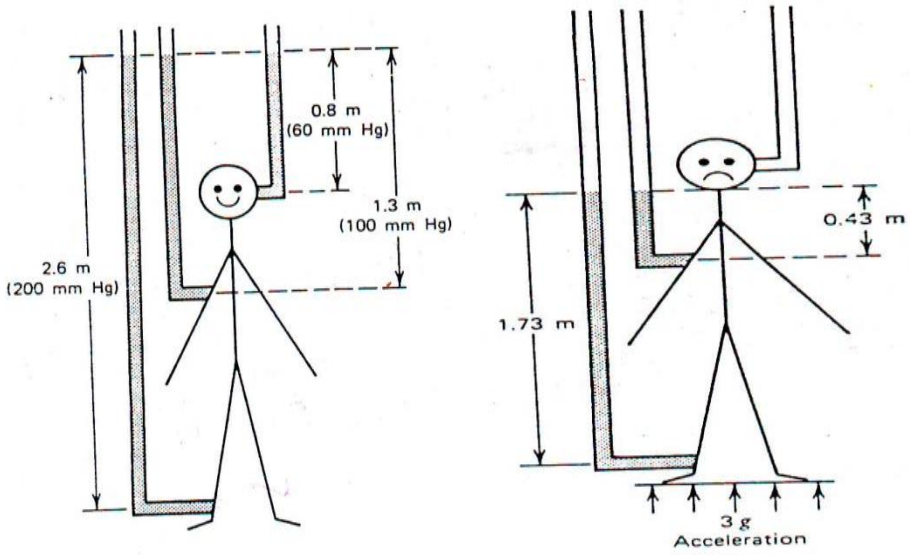
2) The mass of his systemic blood?

The pressure:

The pressure varies from one point to another because of gravitational forces

The greater pressure P in the foot is due to the gravitational force (ρ g h) produced by the column of blood (of height h) between the heart and foot added to the pressure at the heart.

Similarly, the decreased pressure in the head is due to the elevation of the head over the heart



If gravity on earth suddenly became three times greater, blood would rise only about 4.3cm above the heart and it would not reach the brain of a standing person.

This situation can be produced artificially by acceleration the body at 3g in vertical direction. This condition produces pooling of blood in the legs.

Blood pressure

Blood pressure is the force of the blood pushing against the artery walls. The force is generated with each heartbeat as blood is pumped from the heart into the blood vessels. Each time the heart beats (contracts and relaxes), pressure is created inside the arteries.

As heart pumps, it forces blood out through arteries that carry the blood throughout body. The arteries keep tapering off in size until they become tiny vessels, called capillaries.

The size and elasticity of the artery walls also affect blood pressure. When the arteries are healthy and dilated, blood flows easily and the heart does not have to work too hard. However, when the arteries are too narrow or stiff, blood pressure rises, the heart gets overworked, and arteries can become damaged.

- **The term blood pressure refers to arterial blood pressure, the pressure in the aorta and its branches.**
- **The pressure is greatest when blood pumped out of the heart into the arteries. When the heart relaxes between beats (blood is not moving out of the heart), the pressure falls in the arteries.**

Two numbers are recorded when measuring blood pressure.

- **The top number, or systolic pressure,(120 mmHg) refers to the pressure inside the artery when the heart contracts and pumps blood through the body.**
- **The bottom number, or diastolic pressure,(80 mmHg) refers to the pressure inside the artery when the heart is at rest and is filling with blood.**
- **Pulse pressure is the difference between systolic pressure and diastolic pressure. The top number (systolic) minus the bottom number (diastolic) is the pulse pressure. For example, if the resting blood pressure is 120/80 millimeters of mercury (mm Hg), the pulse pressure is 40 —, which is considered a healthy pulse pressure. Generally, a pulse pressure greater than 40 mm Hg is unhealthy.**
- **Four major factors interact to affect blood pressure: cardiac output, blood volume, peripheral resistance, and viscosity. When these factors increase, blood pressure also increases.**
- **Measuring Blood Pressure**

  Blood pressure measured with a sphygmomanometer and stethoscope, and recorded as the systolic pressure over the diastolic pressure.

B.P. Apparatus

Stethoscope