

Title: Physiology of the cardiovascular system /Heart and Circulation/

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I. Physiology of cardiac muscle

A. The heart is composed of two syncytiums: atrial and ventricular, that are separated by fibrous tissue. The heart muscle fibers are typical striated muscle fibers, with some features typical for smooth muscle fibers.

B. The action potential in cardiac muscle

1. The resting membrane potential of cardiac muscle is - 85 mV
2. The depolarization is caused by opening: fast sodium channels and slow calcium channels.
3. The repolarization is caused by opening calcium and potassium channels.
4. The obligatory refractory period of cardiac muscle- between onset of depolarization to drop of cell potential to -65 mV. The relative refractory period - between potential -65 mV to - 85 mV.

C. Contraction of cardiac muscle.

1. excitation-contraction coupling- the mechanism by which the action potential causes the myofibrils to contract.
2. The cardiac cycle- the period from beginning of one heartbeat to the beginning of the next it consists of:
 - a. The period of contraction (systole)
 - b. The period of relaxation (diastole)
3. The systole consists of : isovolumic (isometric) contraction and ejection

The diastole consists of : isovolumic (isometric) relaxation and filling of the ventricle.

4. The filling of the ventricle consists of : rapid filling, slow filling and atria contraction.

5. The force of the heart muscle contraction depends on:

- a. Heterotropic mechanism (Frank-Starling mechanism)
Homotropic mechanism - sympathetic stimulation
- b. Heart rate

6. Hemodynamic parameters:

- a. The end diastolic volume (120 ml)- volume of the ventricle at the end of the diastole
- b. The end diastolic pressure (15 mm Hg)- the pressure in the ventricles at the end of the diastole
- c. Stroke volume output (70 ml)- the volume of blood ejected during systole
- d. Ejection fraction (60-70 %) - the fraction of the end diastolic volume that is ejected
- e. Cardiac output (5-6 liters) the amount of blood that is ejected during 1 minute
- f. Cardiac index (2,8- 3,6 l/min/m²)- cardiac output per 1 m² of the body surface.

D. The valves.

a. Function is prevention of the backflow of blood into the heart

- b. Semilunar valves (pulmonary and aortic) prevent backflow of blood from great arteries (pulmonary trunk and aorta) to the ventricles
- c. Atrioventricular valves (mitral and tricuspid) prevent backflow of blood from ventricles to atria.
- d. The opening and closing of the heart valves is the result of pressure gradient between two sides of the valve cusps.
- e. Heart sounds result from the closing of valve and turbulence of the blood against the inner heart wall. They are described as first and second heart sounds (S1 and S2). S1 is louder and longer, S2 is softer and sharper.
- f. The first sound due to closure of AV valves. The second one due to closure of aortic and pulmonary valves. The third and the fourth- diastolic during ventricular filling. Valves on the right side of the heart open first but close last.

E. Rhythmic excitation of the heart.

1. The excitatory and conductive system consists of:

- α. Sinus node
- β. The internodal pathways
- γ. The atrio-ventricular node
- δ. The a-v bundle
- ε. The left and right bundles of Purkinje fibers

2. Physiology of excitatory and conductive cells:

- a. Resting potential - 60 mV
- b. The depolarization caused by opening of calcium channels
- c. The repolarization caused by opening of potassium channels
- d. The rate of self excitation: the sinus node- 60-80/min ; the a-v node 40-60/min; bundles of Purkinje fibers- 15-40/min

3. The role of the excitatory and conductive system:

- a. Excitation of the heart
- b. Ensures synchronic work of atria and ventricles
- c. Enables almost simultaneously contraction of the ventricles

F. The coronary circulation.

- 1. The left coronary artery divides into anterior intraventricular and circumflex artery and supplies blood to the left ventricle, part of the right ventricle, peripheral parts of excitatory and conductive system.
- 2. The right coronary artery divides into marginal and posterior intraventricular artery and supplies the right ventricle, sinus node and a-v node.
- 3. The blood flow through left coronary artery is greater during diastole, through right coronary artery during systole.

II. Overview of the circulation

A. The cardiovascular system has two major divisions: a pulmonary circuit and systemic circuit. The right side of the heart sends blood to the pulmonary circuit. The left side of the heart sends blood to the systemic circuit.

1. The functional parts of the circulation:
 - a. The arteries
 - b. The arterioles
 - c. The capillaries
 - d. The venules
 - e. The veins
 2. The volumes of the blood in different parts of the circulation:
 - a. 84% in the systemic circulation
 - b. 9% in the pulmonary circulation
 - c. 64% in the veins
 - d. 13% in the arteries
 - e. 7% in the arterioles and in the capillaries
 3. The functional compartments of the cardiovascular system:
 - a. High pressure and low volume compartment
 - b. Low pressure and large volume compartment
 - c. Arterioles with high resistance
 - d. Capillaries
 - e. Arteriovenous anastomoses
 4. The venous return- amount of blood that flows back to the heart depends of three forces:
 - a. Acting from the back
 - b. Acting from the lateral
 - c. Acting from the front
 5. The pressures in various parts of the circulation:
 - a. Systemic circulation.
 - Aorta and great arteries- about 100 mm Hg
 - Arterioles-30-35 mm Hg
 - Capillaries at arteriolar ends - 30-35 mm Hg, 10 mm Hg at venous ends
 - Vena cava- 0 mm Hg
 - b. Pulmonary circulation
 - Pulmonary artery 16 mm Hg
 - Pulmonary veins- 7 mm Hg
 6. The microcirculation plays role in exchange nutrients and other substances between the blood and interstitial fluid. At the arterial ends there is filtration, at the venous ends there is reabsorption . To the forces that play role in this exchange belong:
 - a. The capillary pressure
 - b. The interstitial fluid pressure
 - c. The plasma colloid osmotic pressure
 - d. The interstitial fluid colloid osmotic pressure
 7. The lymphatic system plays role in:
 - a. The concentration control of proteins in the interstitial fluids
 - b. The volume control of the interstitial fluid
 - c. The pressure control of the interstitial fluid
- The fat absorption from the gastrointestinal tract