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## Chapter I

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### Properties of the myocardium

**The heart** pumps the blood along the vascular networks, providing the oxygen and nutrients needed by the organs and tissues and removes toxic substances. Thus, the cardiovascular system has three components with a functional role:

1. **HEART**, muscular organ, with a double pump function, the left heart having a role in maintaining the large circulation (of high pressure, systemic) and the right pump having a role in maintaining the pulmonary circulation;
2. **BLOOD**
3. vascular system:**systemic and pulmonary circulation**, connected in series. It constitutes of:
  - **arteries** which are blood vessels that distribute oxygenated blood:
    - *elastic type arteries* (large arteries: aorta, subclavian, carotid, iliac), with a conduction role; these transform the pulsatile blood flow (generated by the rhythmic activity of the heart) into a continuous flow;
    - *muscular type arteries* (medium arteries) involved in vasoconstriction and vasodilatation, constituting the resistance territory;
    - *arterioles and metaarterioles*.
  - **capillaries and postcapillary venules** which play a role in carrying out the exchange between blood and tissues;

- **veins** – collect blood, ensuring its return to the heart and have the function of a blood reservoir, containing approximately 65% of the total blood volume.

From the inside out, the heart is made up of:

- **endocardium**: lines the cardiac chambers on the inside, having a protective role; it consists of cells similar to endothelial cells and, through direct contact with intracavitary blood, prevents the formation of thrombi through its smooth surface; it has the least vascularization among the three layers, being the first to be affected during ischemic processes;
- **myocardium** (heart muscle): ensures the pump function of the heart, being formed of modified muscle fibers, cardiomyocytes; it is more present at the level of the ventricular structures, especially at the level of the interventricular septum and the left ventricle;
- **pericardium**: it has the 2 layers, the serous (visceral), also known as the epicardium, and the fibrous (parietal) layer; these leaflets delimit the pericardial space which contains a small amount of pericardial fluid. The pericardium has a protective, fixing and mechanical role, reducing the friction of the cardiac walls.

The accumulation of **more than 50 ml** of liquid in the pericardial space is called **liquid pericarditis**, being frequently of neoplastic, tuberculous or autoimmune etiology. Clinically, it is manifested by precordial pain, pericardial friction, and diffuse changes appear on the ECG, such as: ST elevation with PR depression and global decrease in path amplitude (low voltage complexes).

### **PROPERTIES OF THE MYOCARDIUM**

- EXCITABILITY/ bathmotropic function;
- AUTOMATISM / chronotropic function;
- CONDUCTIVITY/ dromotropic function;
- CONTRACTILITY/ inotropic function;
- RELAXATION/ lusitropic function.

## Excitability (bathmotropic function)

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It is the property of the myocardial cell to respond to stimuli by producing a propagated action potential. The myocardial cell has a special property: it is excitable only in diastole to ensure the role of a rhythmic pump (in systole it is in the absolute refractory phase) - ***the law of periodic inexcitability of the heart***.

The membrane of the myocardial cell is polarized, because there is an unequal distribution of electrical charges on either side of the membrane, through the permanent activity of ***membrane transport systems*** at rest.

When a stimulus with threshold intensity acts on a myocardiocyte, structural changes occur in the canalicular proteins, causing them to open. The passage of ions through specific membrane channels generates ionic currents of two types:

- ***Depolarizing current***, which causes the intracellular penetration of positive charges (Na, Ca), decreasing the electronegativity;
- ***Repolarizing current***, which causes positive charges (K) to leave the cell, increasing the electronegativity inside the cell.

**Transmembrane transport systems** are represented by:

### 1. Ion channels

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#### **K channels**

a. ***Inwardly rectifying potassium channels (Kir)*** - active in the resting phase; these are of several types:

- **Kir (K1)** role in maintaining the resting potential around -90 mV;
- **K<sub>ATP</sub>** (ATP-dependent potassium channels), metabolically regulated: are stimulated (opened) by reduction of intracellular ATP (normal ATP levels block activation), producing membrane hyperpolarization (via K efflux):
  - in conditions of ischemia (ischemia is accompanied by ATP depletion), hyperpolarization causes a decrease in myocardial contractility, thus protecting it;
- **mediator-dependent potassium channels** (Ex: adenosine, acetylcholine, etc.) are activated through specific receptors.

b. **Voltage-gated potassium channels** are slowly activated after depolarization, playing a role in repolarization and determining the action potential duration:

- **outward transient potassium current** ( $I_{to}$ ): responsible for phase 1 of the AP;
- **the slow potassium channel,  $K_s$**  (slow);
- **fast potassium channel,  $K_r$**  (fast);
- **ultrafast potassium channel,  $K_{ur}$**  (ultrarapid current), determines the shorter duration of AP, being present at the level of the atria.

**Voltage dependent Na channels** are active in phase 0 of rapid depolarization

**Voltage dependent Ca channels** are of 2 types:

a. **Type L** (long lasting)

- have an activation threshold of -40 mV;
- it activates slowly;
- are found in:
  - working myocardial fibers => phase 2 of AP;
  - node cells => phase 0 of AP;
  - skeletal muscles => excitation-contraction coupling.

b. **Type T** (transient)

- have an activation threshold at more electronegative values of the membrane potential (< -40 mV);
- it activates quickly;
- are found at the level of the NSA => repetitive BP discharges (diastolic depolarization).

**Non-selective ion channels:**

a. channels that mediate the **pacemaker current,  $I_f$**  (the funny current) and take part in the spontaneous diastolic depolarization of cells with automatism; this means that:

- are activated by hyperpolarization;
- cause the entry of intracellular  $Na^+$  (occasionally also the transfer of  $K^+$ );

- ivabradine and acetylcholine inhibit these channels.
- b.** channels that are *stretch activated*, permeable especially for Ca, are responsible for mechano-electrical feedback and have arrhythmogenic potential.

## 2. Ion pumps –primary active transport systems

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### a. *ATP-ase dependent of Na and K*

- it is electrogenic: it actively introduces 2 K<sup>+</sup> ions into the cell and removes 3 Na<sup>+</sup> ions;
- is inhibited by digitalis.

### b. *ATP-ase dependent of Ca*

- forces cytoplasmic Ca out.

## 3. Ion exchangers

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### a. *the Na<sup>+</sup>/Ca<sup>++</sup> exchanger*

- located especially at the level of the T-tubes;
- is a voltage-sensitive system:
  - negative potentials (< -40 mV) expel Ca;
  - more positive potentials (> -40mV) introduce Ca into the cell.

### b. *the Na<sup>+</sup>/H<sup>+</sup> exchanger*

- intervenes in conditions of myocardial ischemia, protecting the heart from intracellular acidosis

## Action potentials in the myocardium

Depending on the speed of depolarization, two types of myocardial fibers are differentiated:

- a.** with *fast answer*– atrial myocytes, Purkinje fibers and ventricular myocytes; AP has 5 distinct phases;
- b.** with *slow answer*– in ASN, AVN; AP is conducted in only 3 phases.

