Cardiovascular system (PART 1)

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Lec. 5

Cardiovascular system

❖ **The cardiovascular system has two primary components**:

➢the heart

➢and blood vessels.

❖Its primary function is to transport nutrients and oxygen-rich blood to all parts of the body and to carry deoxygenated blood back to the lungs.

Heart

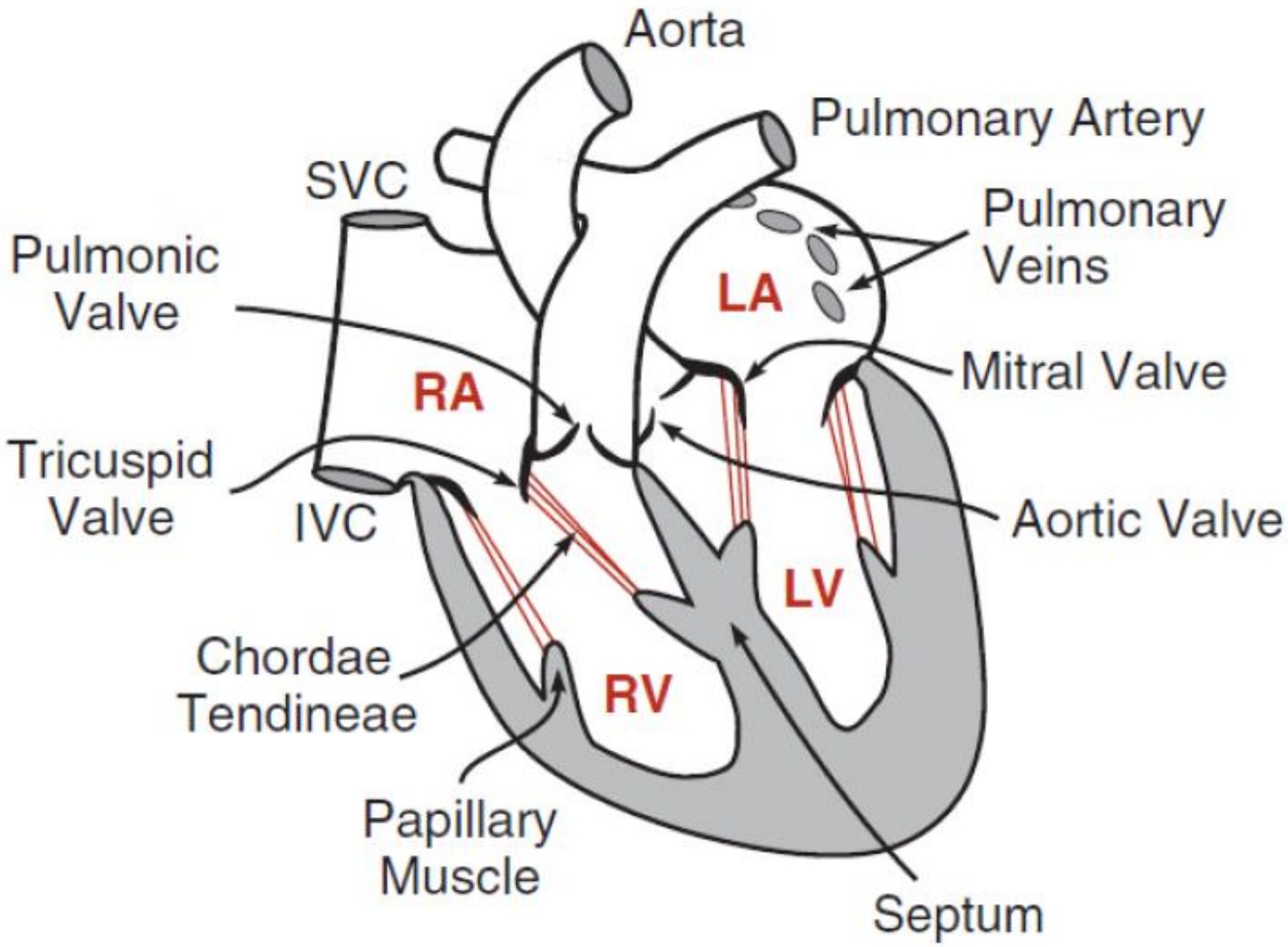
❖ **The heart** is a specialized muscular organ that rhythmically contract and pumps blood from low pressure venous side to the high-pressure arterial side of the circulation.

❖The heart has other important functions besides pumping blood:-

➢It is synthesizing several hormones. One of these hormones, ***atrial natriuretic peptide***, plays an important role in the **regulation** of blood volume and blood pressure.

➢***Sensory nerve receptors associated with the heart*** play a role in **regulating** the release of antidiuretic hormone from the posterior pituitary, which regulates water loss by the kidneys.

- **Heart consists of four chambers: Right atrium, Right ventricle, Left atrium, and Left ventricle.**



Origin and spread of cardiac excitation

❖The process of *converting an electrical stimulus* (**action potential**) into a *mechanical response* (**muscle contraction**) it is **called** ***excitation***.

❖In the **heart** the *origin of excitation started from* **SA node** *that stimulate the* **myocardium of both left and right atrium** and *then inter the ventricles through the* **AV node** (that slowed this impulse), **bundle of His**, *left and right branches*, **Purkinje fibers** *and finally to all* **ventricular cells**.

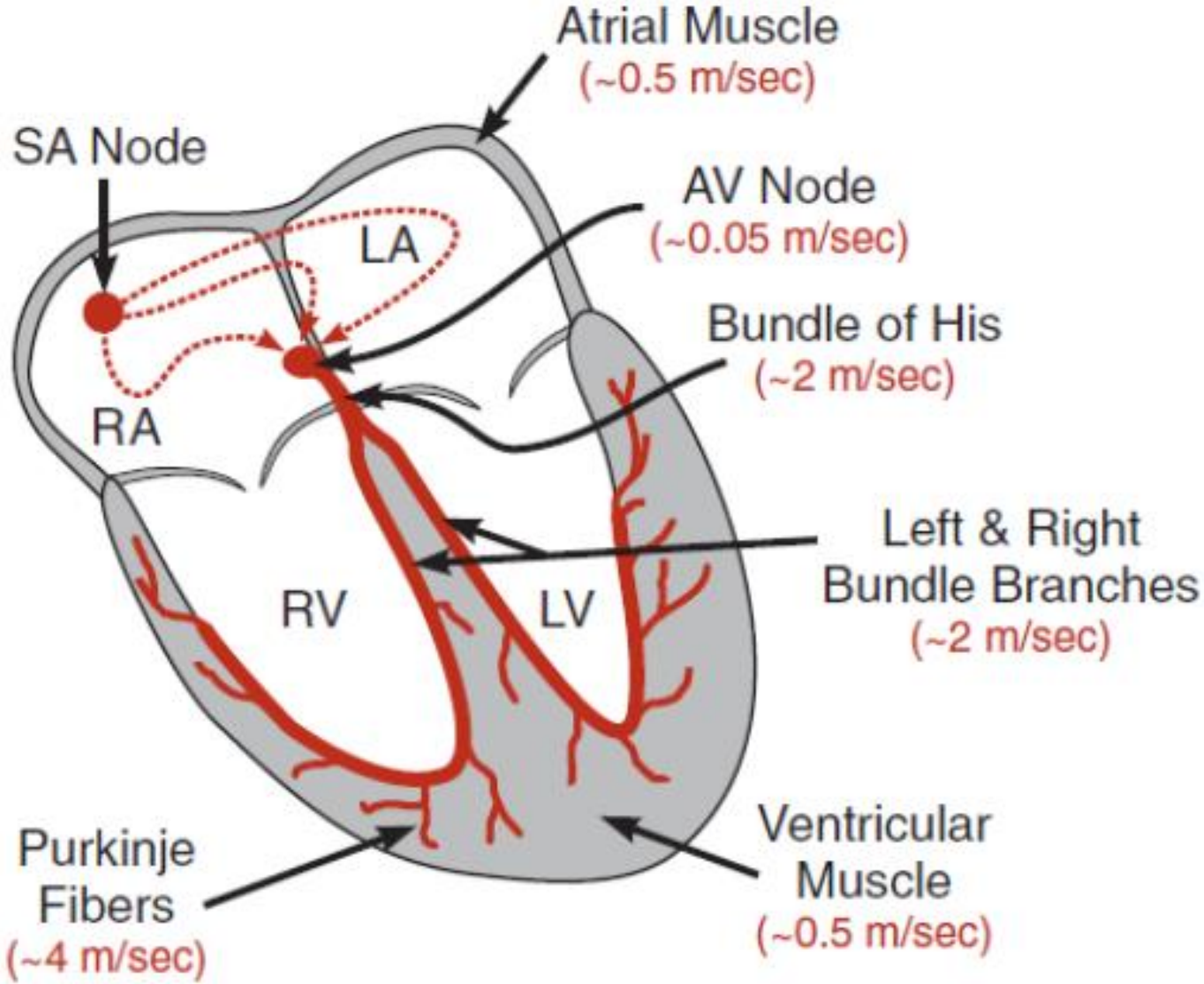


FIGURE 2.10 Conduction system within the heart. Conduction velocities of different regions are noted in parentheses. Note that Purkinje fibers have the highest conduction velocity and the atrioventricular (*AV*) node has the lowest conduction velocity. *SA*, sinoatrial; *RA*, right atrium; *LA*, left atrium; *RV*, right ventricle; *LV*, left ventricle.

CELL MEMBRANE POTENTIALS

- The primary function of cardiac myocytes is to *contract*. the electrical changes within the myocytes initiate this contraction.

➢ **Resting Membrane Potentials**

➢ **Action potentials**

Resting Membrane Potentials

- Cardiac cells, like all living cells in the body, have an electrical potential across the cell membrane.
- In the **resting membrane potential** *inner side of membrane high electronegatively about* -90 mV as explained in the figure below.
- **This resting membrane potential (Em) is determined by:-**

- the **concentrations** of positively and negatively charged ions across the cell membrane,
- the **relative permeability** of the cell membrane to these ions,
- and the **ionic pumps** that transport ions across the cell membrane.

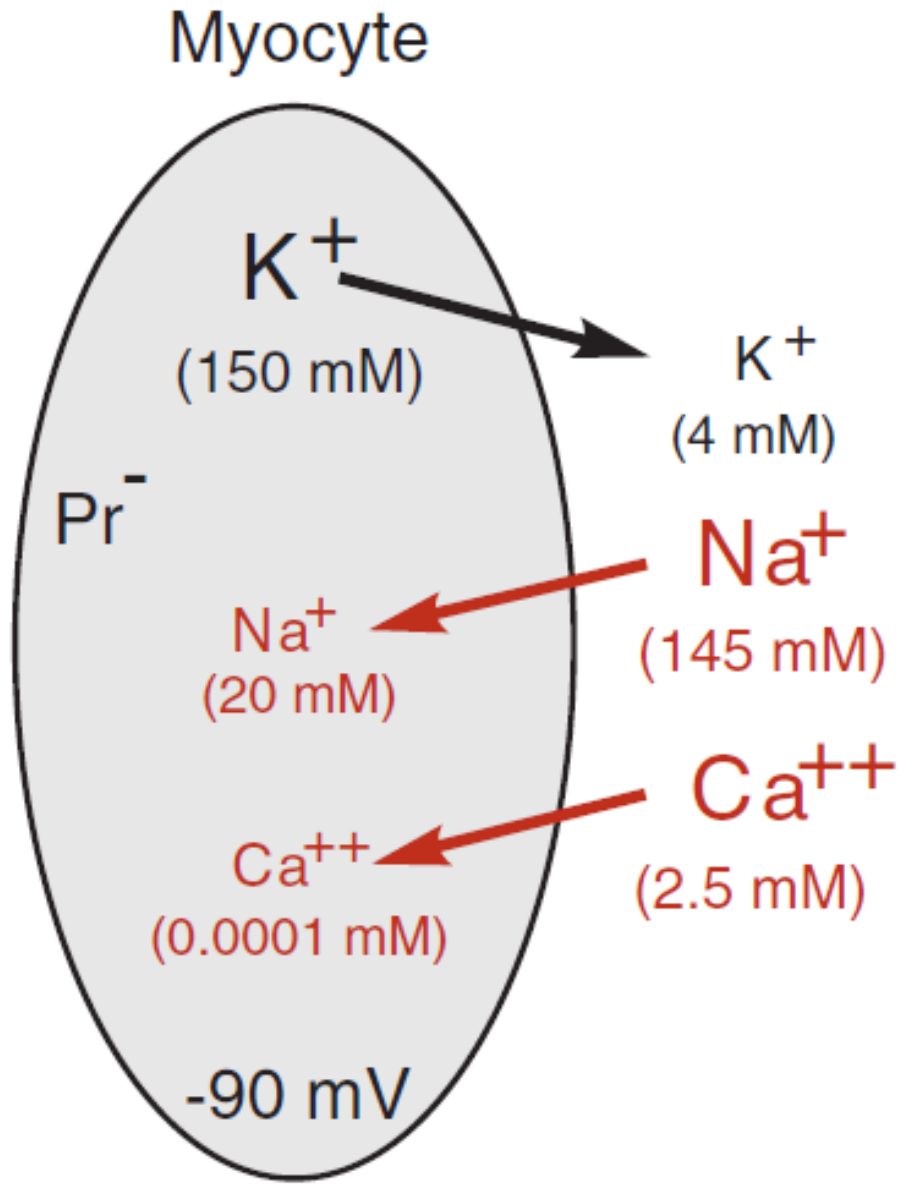


FIGURE 2.1 Concentrations of K^+, Na^+, and Ca^{++} inside and outside a cardiac myocyte at a resting membrane potential of −90 mV. *Pr⁻*, negatively charged proteins.

Ion Channels

❖**Two general types of ion channels exist:-**

- voltage-gated (voltage-operated) channels
- Receptor gated (receptor-operated) channels.

❖**Voltage gated channels** open and close in response to **changes** in *membrane potential*

➢**Examples** of voltage-gated channels include several *sodium*, *potassium*, and *calcium channels* that are involved in cardiac action potentials.

❖**Receptor-gated channels** open and close in **response to** *chemical signals* operating through membrane receptors.

➢**For example**, *acetylcholine*.

Action potentials

- **Action potentials** ***occur*** *when the membrane potential suddenly* depolarizes *and then* repolarizes *back to its resting state*.
- **The two general types of cardiac action potentials include:-**
- 1- PACEMAKER ACTION POTENTIALS (sinoatrial node, SA node, and atrioventricular node, AV node)
- 2- non- PACEMAKER ACTION POTENTIALS (myocardium cells)
- **Note**: *Non-pacemaker action potentials are triggered by depolarizing currents from adjacent cells, whereas pacemaker cells are capable of spontaneous action potential generation.*

- **Both types of action potentials in the heart differ considerably from the action potentials found in nerve and skeletal muscle cells (Fig. 2.4).**

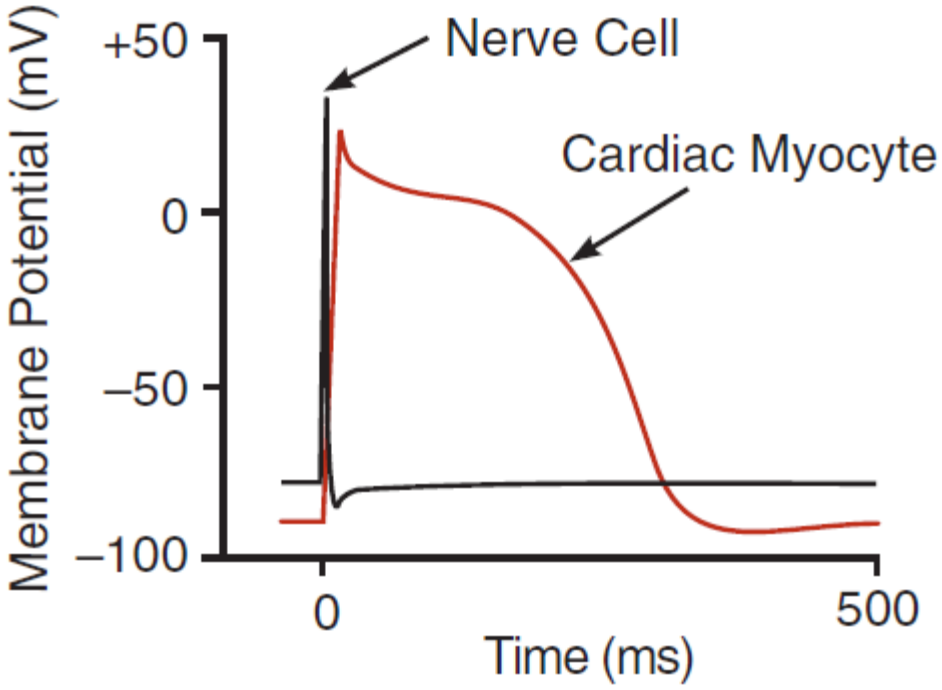


FIGURE 2.4 Comparison of action potentials from a nerve cell and a nonpacemaker cardiac myocyte. Cardiac action potentials are much longer in duration than nerve cell action potentials.

- One major difference is the *duration of the action potentials*. In a typical **nerve**, the action potential duration is about *1to 2 milliseconds*.
- In **skeletal muscle cells**, the action potential duration is approximately 2 to 5 milliseconds.
- In contrast, the *duration of ventricular action potentials* ranges from 200 to 400 milliseconds.
- These differences among nerve, skeletal muscle, and cardiac myocyte action potentials relate to *differences in the ionic conductances responsible for generating the changes in membrane potential.*

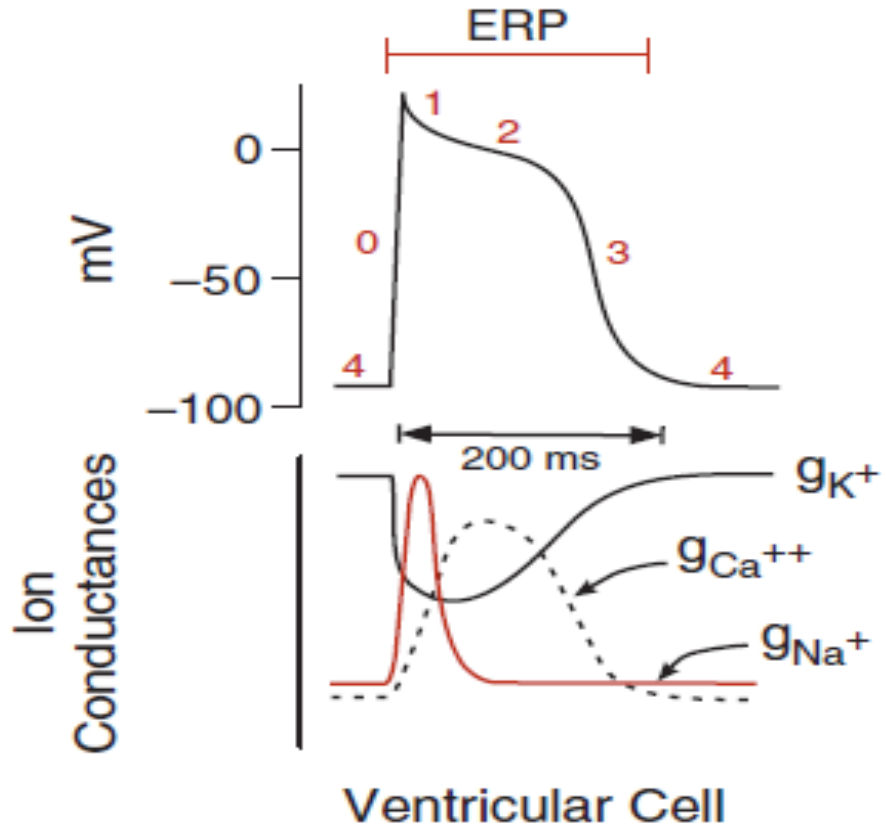


FIGURE 2.5 Changes in ion conductances associated with a ventricular myocyte action potential. Phase 0 (depolarization) primarily is due to the rapid increase in sodium conductance (gNa^+) accompanied by a fall in potassium conductance (gK^+); the initial repolarization of phase 1 is due to opening of special potassium channels (I_{to}); phase 2 (plateau) primarily is due to an increase in slow inward calcium conductance (gCa^{++}) through L-type Ca^{++} channels; phase 3 (repolarization) results from an increase in gK^+ and a decrease in gCa^{++}. Phase 4 is a true resting potential that primarily reflects a high gK^+. *ERP,* effective refractory period.

Phases during action potential in non-pacemaker myocardium

- **1- phase 4** (resting membrane): in this phase the membrane in the resting state that mean the charge in inner side highly negative.
- **2- phase 0** (depolarization): in this phase when the cell is stimulated by either *sodium* or *calcium*, so, the *electronegativity* in the inner side **decreases** approximately from -90 to -40, this points it called threshold point in which the *sodium ion inters rapidly* from voltage channel and *changing the charge from negative to positive charges*.
- **3- Phase 1** (initial repolarization): in this phase the *potassium ions efflux* outer cell membrane.
- **4- Phase 2** (plateau): in this phase increase in slow *inward calcium ion*.
- **5- Phase 3** (repolarization): in this phase the *channel of calcium closed* and *increase in efflux of potassium* ion **until reach** to *resting membrane*.

❖**NOTE:** *During phases 0, 1, 2, and part of phase 3*, the cell is refractory (i.e., unexcitable) to the initiation of new action potentials.

❖This is the **effective (or absolute) refractory period** (ERP, or ARP). During the ERP, stimulation of the cell does not produce new, propagated action potentials because the h-gates are still closed.

❖The ERP acts as a protective mechanism in the heart by limiting the frequency of action potentials (and therefore contractions) that the heart can generate.

➢This enables the heart to have adequate time to fill and eject blood.

➢The long ERP also prevents the heart from developing sustained, tetanic contractions (is a sustained muscle contraction) like those that occur in skeletal muscle.