Cardiovascular system

2nd lecture

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Pacemaker Cells and the Cardiac Conduction

- System Pacemaker cells make up only about 1% of the total number of cardiac muscle cells. There are three populations of these cells in the heart that are capable of spontaneously generating action potentials, thereby setting the pace of the heart.
- These three cell populations are collectively called the cardiac conduction system. After looking at how pacemaker cells generate action potentials.
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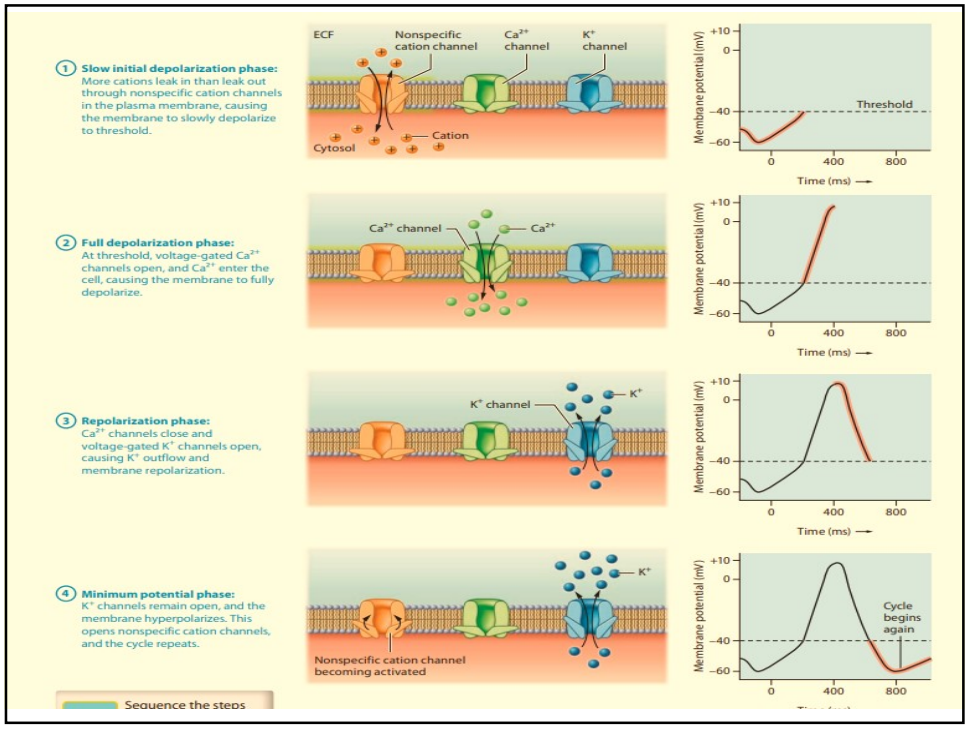
Pacemaker Cell Action Potentials

- the electrical tracing produced by an action potential of a pacemaker cell, called a pacemaker potential, is much different in appearance from that of a contractile cell. For one, the depolarization in a pacemaker cell occurs much more slowly.
- This is due in part to the lack of voltage-gated sodium ion channels in the pacemaker sarcolemma. In addition, pacemaker cell action potentials lack a plateau phase. Finally, notice that the pacemaker cell membrane potential oscillates—that is, it never remains at a resting level and instead occurs in a cycle, with the last event triggering the first.

- This is possible because of nonspecific cation channels that are unique to pacemaker cells. These channels open when the membrane reaches a minimum potential after repolarization, and their opening starts

- 1 Slow initial depolarization phase.We start a pacemaker potential with the plasma membrane in a hyperpolarized state—it is at its minimum membrane potential. This state opens nonspecific cation channels in the membrane. These channels allow more sodium ions to leak into the cell than potassium ions to leak out, which results in an overall slow depolarization to threshold.
- 2 Full depolarization phase. When the membrane reaches threshold, voltage-gated calcium ion channels open, allowing calcium ions to enter the cell and thereby causing the membrane to fully depolarize. This causes the slow upstroke of the tracing that you see in Figure 17.11.
- Notice that this upstroke is not as rapid as that in contractile cell depolarization. This is because calcium ions enter more slowly than sodium ions as a result of differences in channel structure

- 3 Repolarization phase. Recall that calcium ion channels are time-gated for closing, so after a certain time (about 100– 150 msec), they close. At the same time, voltage-gated potassium ion channels begin to open. This allows potassium ions to exit the cell, and the membrane begins to repolarize.
- 4 Minimum potential phase. Potassium ion channels remain open until the membrane reaches its minimum potential. When this happens, the membrane is hyperpolarized, which opens the nonspecific cation channels, and the cycle begins again.



Anatomy of the Cardiac Conduction System

- The cardiac conduction system includes the following three populations of pacemaker.

1- Sinoatrial node.

The sinoatrial node or SA node, is located in the upper right atrium slightly inferior and lateral to the opening of the superior vena cava.

- Under normal conditions, the SA node has the fastest intrinsic rate of depolarization—about 60 or more times per minute, a rate that is subject to influence from the sympathetic and parasympathetic nervous systems

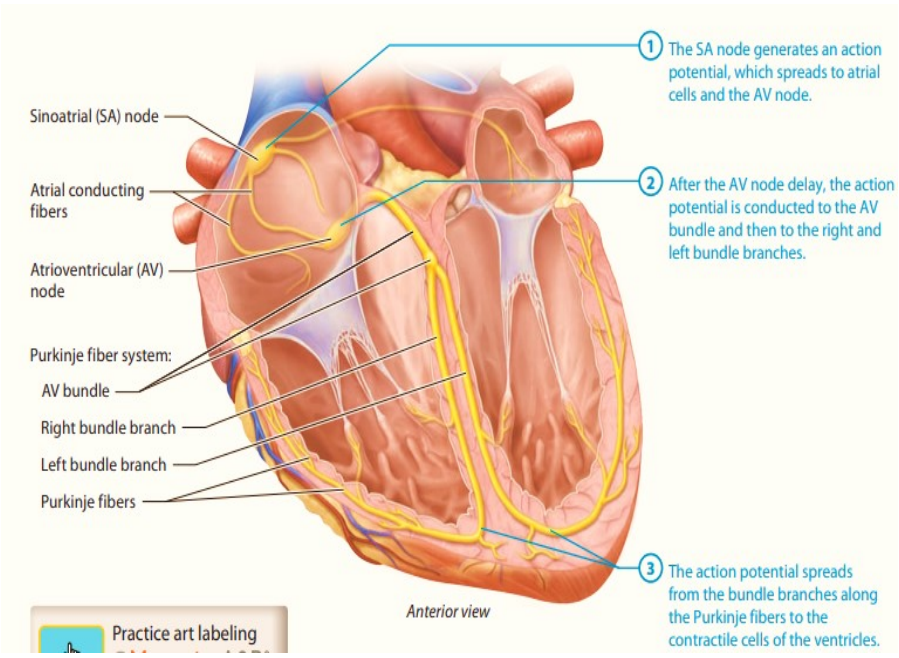
2- Atrioventricular node.

The atrioventricular node, or AV node, is a cluster of pacemaker cells located posterior and medial to the tricuspid valve. It is slower than the SA node, with an intrinsic rate of only about 40 action potentials per minute.

3- Purkinje fiber system.

- The slowest group of pacemaker cells is collectively called the Purkinje fiber system its cells depolarize only about 20 times per minute. The cells of this system are sometimes called atypical pacemakers, because their action potentials rely on different ion channels and they function in a slightly different way.

- The atrioventricular bundle (AV bundle) penetrates the heart's fibrous skeleton in the inferior interatrial septum and the superior interventricular septum.
- The right and left bundle branches course along the right and left sides of the interventricular septum, respectively. Then the terminal branches penetrate the ventricles and finally come into contact with the contractile cardiac muscle cells.



The Electrocardiogram

- One of the most important clinical tools for examining the health of the heart is the electrocardiogram, or ECG
- which is a graphic depiction of the electrical activity occurring in all cardiac muscle cells over a period of time.
- An ECG is recorded by placing electrodes on the surface of a patient's skin: six on the chest and two on each extremity. These electrodes record the changes in electrical activity from unique positions in the heart. These electrical changes are shown on the ECG as deflections, or waves.

The waves of an ECG include the following:

- P wave.

The small, initial P wave represents the depolarization of all cells within the atria except the SA node.

The P wave nearly always registers as an upward deflection on the ECG. Figure shows a flat segment immediately preceding the P wave that represents the time period during which the SA node depolarizes.

- QRS complex.

The large QRS complex, which represents ventricular depolarization, is actually three separate waves.

1- Q wave is the first downward deflection,

2- R is the large upward deflection,

3- S is the second downward deflection.

The QRS is usually much larger in magnitude than the P wave because of the size differences between the atria and ventricles.

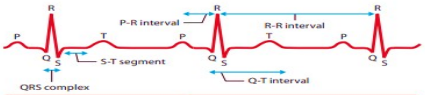
Note that atrial repolarization occurs as the ventricles depolarize.

- T wave.

The small T wave occurs after the S wave of the QRS complex and represents ventricular repolarization.

The T wave is an upward deflection under normal conditions.

However, certain pathological states, such as myocardial ischemia, may cause the T waves to become inverted as a result of functional changes in the cells' electrical activity when the oxygen level is inadequate.



ECG FINDING	MEANING
P wave	Atrial depolarization
QRS complex	Ventricular depolarization (masking atrial repolarization)
T wave	Ventricular repolarization
R-R interval	Entire duration of a cardiac action potential
P-R interval	Duration of atrial depolarization and AV node delay
Q-T interval	Entire duration of a ventricular action potential
S-T segment	Ventricular plateau phase