Electrical Activity in the Heart

Model 1: The Excitation-Conduction System of the Heart

About 99% of the cardiac muscle fibers in one’s heart contract to pump blood. The other 1% are specialized cells called “pacemaker cells” that conduct electrical impulses and can even spontaneously generate action potentials. Although pacemaker cells in different regions of the heart have different rates of generating action potentials, usually the cells with the fastest rate act as the heart’s pacemaker.

QUESTIONS:

1. Use each **bold term** described below to label the specialized excitation-conduction system of the heart in Model 1:

   - The **SA node (sinoatrial or sinus node)** is located in the right atrium near the entrance of the superior vena cava. The SA node contains cells that spontaneously generate action potentials at a rate of 80-100 beats/minute.
   - The **AV node (atrioventricular node)** is located at the junction between the atria and ventricles. Action potentials are propagated through the AV node very slowly. The AV node contains cells that spontaneously generate action potentials at a rate of 40-60 beats/minute.
   - The **AV bundle** in the interventricular septum receives electrical activity from the AV node. This is the only pathway for electrical activity to move from the atria to the ventricles.
   - Action potentials propagate from the AV bundle through the **bundle branches** to **Purkinje fibers**, which are large-diameter cells that propagate action potentials very rapidly to contractile myocardial cells throughout the ventricles. Purkinje fibers spontaneously generate action potentials at a rate of 20-40 beats/minute.

2. Before continuing, decide as a group which part of the intrinsic electrical system serves as the normal pacemaker for the heart. Explain your answer below:
**Model 2: The Sequence of Electrical Excitation in the Heart**

Model 2 shows the pathway of electrical excitation that passes over the heart (*darkened areas in the diagram indicate electrical excitation*). In some areas the electrical activity spreads via the specialized conducting cardiac muscle cells. In other areas action potentials spread from one cardiac muscle fiber to the next through specializations in the cells’ membranes called gap junctions.

![Diagram of heart model]

**QUESTIONS:**

3. Examine Model 2 and describe what is happening in each of the figures. Include the names of specific electrical system structures when they are involved. Figures A and B are described to get you started.

   **A:** *rest (no electrical excitation)*

   **B:** *SA node has generated an action potential which is starting to spread over the atrial muscle mass*

   **C:**

   **D:**

   **E:**
Model 3: Electrocardiogram (EKG or ECG)

The electrocardiogram (ECG) shows a record of electrical activity in the heart. An ECG records the sum of all the electrical events occurring in all the cells of the heart at any point in time. Each wave represents either a depolarization (the membrane potential during the early part of an action potential when the membrane potential is less negative than at rest) or a repolarization (the membrane potential during the later stages of an action potential when the membrane potential is returning to its resting state).

The P wave corresponds to depolarization of the atria; the QRS complex corresponds to depolarization of the ventricles; the T wave corresponds to repolarization of the ventricles.

QUESTIONS:

4. Place an arrow on the ECG recording in Model 3 to indicate the SA node generating an action potential.
5. Although the ECG does not directly measure mechanical events, scientists and clinicians make assumptions about the heart’s mechanical activity based on the ECG. Answer the following questions about this relationship between the ECG and the heart’s mechanical activity using information from Models 1, 2 and 3:

a) What does the P wave represent?

Predict the mechanical event that follows the P wave.

b) What does the QRS complex represent?

Predict the mechanical event that follows the QRS complex.

c) What does the T wave represent?

Predict the mechanical event that follows the T wave.
Model 4: ECG and Selected Arrhythmias

ECGs are helpful in determining changes and irregularities (arrhythmias) in the heart’s excitation-conduction system. Below are 4 ECG recordings that show a normal heart rate of 75 beats/min and three examples of normal changes in SA Node activity.
QUESTIONS:

6. Lance Armstrong has a resting heart rate of 35 beats/minute. Which recording shown in Model 3 could be Lance’s at rest? Explain your answer:

7. When Lance is pedaling up a mountainside, his heart rate is 150 beats/minute. Which recording in Model 3 could be Lance’s during strenuous exercise? Explain your answer:

8. Most people have a change in heart rate associated with breathing, e.g. heart rate often increases with inhalation and decreases with exhalation.
   a) Which recording in Model 3 shows this condition?
   b) How can you determine if you have the condition described in your answer to 8a? Do you have this condition?

9. People have been known to live without atrial depolarization. What would an ECG look like in a person with this condition? Write a sentence or draw an ECG to explain your answer.

10. Given that people can live without atrial depolarization, do you think people can live without ventricular depolarization? Explain.
MODEL 5: Ventricular Fibrillation
Basketball player Hank Gathers collapsed and died during a college basketball game. The cause of his collapse was an irregular heartbeat. He suffered from exercise-induced ventricular tachycardia but developed ventricular fibrillation during the game. An automated external defibrillator (AED) was used to try and treat him for this condition.

QUESTIONS:
11. Describe how this ECG of ventricular fibrillation compares to the normal ECG in Model 3.

12. What is the heart rate of the ECG shown in Model 5? Explain.
13. **Ventricular fibrillation (V-fib)** is a condition of uncoordinated contraction of the cardiac muscle of the ventricles, making them quiver rather than contract properly. People who are not health professionals usually cannot feel a pulse. Only an ECG can confirm such an arrhythmia.

As a group, explain why this is a medical emergency that requires prompt treatment.

14. Is V-fib the same as or different from the person in question 10 who had no ventricular depolarization? Explain.

15. An **automated external defibrillator** or **AED** is a portable electronic device that automatically diagnoses the potentially life threatening cardiac arrhythmias of ventricular fibrillation and ventricular tachycardia. It is also able to treat them through defibrillation, which stops the arrhythmia, allowing the heart to reestablish an effective rhythm.

List three places in your community that you might find an AED.