Heart “Cardio”: 4 chambered muscular pump

- **Function**: Contraction & production of:
  - **Forces blood** through vasculature

  ✓ Delivers:

  ✓ Removes:

  Resting Heart Rate: 60 - 80 bpm
  Single beat pumps: 75-80 mls (1/3 cup)
  Pumps: ~ 5.5 liters per min

  ⇒ Circulates blood volume in 1 min

General Anatomy:

**Myocardium**:

★ Composed of interconnected:

★ Creates 2 functional:

  a. **Atrial Myocardium**:
  
  b. **Ventricular Myocardium**:

    ⇒ Contract & relax as:

    ✓ Contraction:

    ✓ Relaxation:

**Cardiac Cycle**: Complete contraction & relaxation of cardiac muscle

★ Total Cardiac Cycle (Resting) =

  a. Atrial Systole = 0.1 sec (100msec)

    ⇒ Atria:

    ⇒ Atria forcibly:

  b. Atrial Diastole = 0.7 sec (700msec)

    ⇒ Chamber is:

    ⇒ Chamber is:

  c. Ventricle Systole = 0.3 sec (300msec)

    ⇒ Ventricle:

    ⇒ Ventricle forcibly:

  d. Ventricular Diastole = 0.5 sec (500msec)

    ⇒ Ventricles:

    ⇒ Ventricles is:

**Myocardial Specializations:**
1. **Desmosomes:**
   - Cells *physically/structurally*:
     - Adjacent cells become the:
       - **Allows**
     - Myocardial cells arranged in:
       - Contraction results in:
       - **Decrease internal**:

2. **Gap Junctions:**
   - Membrane channels (*connexons*) allow:
     - Movement of:
     - Movement of:
   - **Action potentials** travel through **ALL**:
     - Result: Stimulate **ALL** interconnected cells:

3. **Branched Cardiac Cells:**
   - Myocardial cells are interconnected with:
     - Creates a physical & electrical:
       - **Force** is distributed more:
       - **Current** is distributed more:
       - **Safe guard** providing **multiple routes** for:

   ★ **Significance:** *Many individual myocardial cells* function as a:
   1. Desmosomes:
   2. Gap Junctions:
   3. Branching:
   - Heart functions as:
     - **MYOCARDIUM** Structurally & electrically:

**Cardiac Conduction System**
- 2 populations of specialized:

  A. **Nodal Cells: Initiate Action Potentials:**
     - Spontaneously:
     - Significance: **Stimulate**:

  B. **Conducting Cells: Rapidly conduct**:
Conduction System: Electrical “Hardwiring”

1. **Sino Atrial (SA) Node**: Nodal Cells
   - Location: Superior/Lateral corner of:
   - Function:
     - Initiates:
     - Determines contraction rate:

   • Resulting events:
     a. Current spreads across ALL interconnected:
     - ∗
     - ∗ Conductance across atrial myocardium:
     b. Stimulates:
     c. Important: Current DOES NOT spread to:
     - ∗
     - ∗

2. **Atrioventricular (AV) Node**: Nodal Cells
   - Slow group of:
     - ∗ AV node Conductance:
   - Location: Inferior/medial:
     - ∗ Stimulus:
   - Functional Significance:
     a. Slows:
     - ⇒ Allows Atria to contract before:

3. **Bundle of His (AV Bundle)**: Conducting Cells
   - Location:
     - Functional Significance: Carries stimulus through:
     - ∗ Conductance across AV node:
4. **Bundle Branches** (Rt. & Lft.) : Conducting Cells

- **Location:**
- **Functional Significance:** Divides current to the:

  > Bundle branch Conductance:

5. **Purkinje Fibers** : Conducting Cells

- **Location:** Network throughout:
- **Functional Significance:** Spreads current *quickly* through entire:

  > Purkinje fiber Conductance:

**Clinical Significance:**

**ECG:** Electrocardiogram: Graphic representation of Cardiac Electrical Currents

**Cardiac Action Potentials:**

- **Pacemaker Cells:** SA Node Cells capable of:
  
  ✓

  ✓ *Nodal cells NEVER at:*

  a. Demonstrate **Automaticity:**

  > *Internal ability to coordinate contraction rates*

  ![Cardiac Action Potential Diagram]

b. **Spontaneously Depolarize:**

  - **CNS control:**
    a. Does NOT:
    
    b.

- **Events of Pacemaker Potentials:**

  a. Membrane starts at:

  b. Cells gradually depolarize to:

  ✓ Depolarization results from opening:

  ➞ **Stimulus Voltage:** Hyperpolarization from preceding:

  > Hyperpolarizing toward -50 to -60mV
Hyperpolarization Cyclic Nucleotide channel:

c. HCN channels depolarize membrane to:

d. Voltage Gated Ca\(^{2+}\) channels:

\(\Rightarrow\) Rapid depolarization:

e. Voltage Gated Ca\(^{2+}\) channels:

f. Voltage Gated K\(^{+}\) : Opening of:

\(\Rightarrow\) Rapid:

\(\Rightarrow\) Rapid Depolarization \(\sim +15\text{mV}\)

Sympathetic Control over SA Node:

a. Neurotransmitter:

\(\Rightarrow\) Binds \(\beta 1\) Receptor:

b. Increases concentration of:

c. cAMP binds:

\(\Rightarrow\) Sensitizes:

✓ Opens to a greater degree:

d. Overall Effect: Pacemaker Potentials:

\(\Rightarrow\)

Parasympathetic Nervous System:

a. Neurotransmitter:

\(\Rightarrow\) Binds Muscarinic Receptors:

b. Open K-channels: Increase

c. Nodal Cells more resistant to depolarization:

\(\Rightarrow\) K-efflux counteracts:

\(\Rightarrow\) Lengthens:

Study Questions:
1. Describe the significance of each in the production of a uniform holistic contraction: a. presence of the gap junctions b. presence of desmosomes c. branched arrangement of cardiac cells. How do all three result in the formation of a functional myocardium?

2. Define the term myocardium. Why is it not possible for action potentials generated in the atrial myocardium to easily pass to the ventricular myocardium?

3. What is the cardiac skeleton? Why is it necessary to have a cardiac conduction system? If there wasn’t a cardiac conduction system, how would the cardiac contraction patterns differ?

4. Describe the movement of charge through the cardiac conduction system. Describe the significance of each portion of the system: SA node, AV node, Bundle of HIS (AV Bundle), Bundle Branches, Purkinje Fibers.

5. If AV nodal cells conducted Action Potentials at the same velocity as Bundle branch cells, what would be the resulting effect in cardiac contraction?

6. What is a pacemaker potential? Why are nodal cells incapable of maintaining resting membrane potentials? What channels are responsible for the constant pacemaker depolarizations? List the steps involved in producing pacemaker potentials.

7. What stimulates the HCN channels to open? How is this opening modified by the sympathetic nervous system? (Specifically norepinephrine and cAMP)? What is the overall affect of the sympathetic nervous system on the heart rate?

8. How does the parasympathetic nervous system alter the pacemaker potentials? (What happens to the “ramp to threshold?”) What is the overall affect of the parasympathetic nervous system on the heart rate?

9. What are the differences between the pacemaker potentials and a cardiac myocardial cell potential? Which cells produce the myocardial potentials?