Heart: “Cardio”

- 4 Chambered muscular pump
- Function: Contraction & production of **Hydrostatic Pressure**
  - Forces blood through vasculature
  - Delivers: Nutrients, O₂, minerals, & chemical messengers
  - Removes: Waste, excess & CO₂

General Stats:
- 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: Single contractile unit
* Composition: Interconnected myocardial cells
* Creates: 2 Functioning Syncytiums
  ✓ Single contractile units
a. Atrial Myocardium: Right & Left Atria
b. Ventricular Myocardium: Right & Left Ventricles

⇒ Contract & relax as single units
✓ Contraction: Systole
✓ Relaxation: Diastole

Cardiac Cycle: Complete contraction & relaxation of cardiac muscle
* Total Cardiac Cycle (Rest) = ~0.8sec (800msec)
  a. Atrial Systole = 0.1 sec (100msec)
    ⇒ Atria contracting
    ⇒ Atria forcibly filling Ventricle
  b. Atrial Diastole = 0.7 sec (700msec)
    ⇒ Chamber is relaxed
    ⇒ Chamber is filling passively
c. **Ventricle Systole** = 0.3 sec (300msec)
   - Ventricles **contracting**
   - Ventricles are forcibly **ejecting blood**

d. **Ventricular Diastole** = 0.5 sec (500msec)
   - Ventricles **relaxing**
   - Ventricles are **filling passively**

**Myocardial Specializations:**

1. **Desmosomes**: Strong physical intercellular attachments
Cells physically/structurally interconnected
- Adjacent cells become the "origin" and "insertion" for each other
  ✓ Allows tension to be produced
  ✓ Myocardial cells arranged in a circle

- Contractions result in decreased diameter
  ✓ Decrease internal chamber volume

2. Gap Junctions: Cytoplasmic Cellular Connections

Membrane channels (connexons) allow cytoplasmic exchange
- Movement of IONS between cells
- Movement of Action Potentials between cells
3. Branched Cardiac Cells:

- Myocardial cells are *interconnected* with several other cells.
- Creates a physical & electrical *network*.
  - **Force** is distributed more *uniformly*.
  - **Current** is distributed *quickly*.
  - **Safe guard** providing *multiple routes* for electrical stimuli to travel.

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*Significance:* Many individual myocardial cells function as a single unit.

1. **Desmosomes:** Physically interconnect
2. **Gap Junctions:** Electrically interconnect
3. **Branching:** Effectively distribute

- **Heart functions as “ONE large cell”**
- **MYOCARDIUM:** Structurally & electrically a single functional unit
Cardiac Conduction System

• 2 populations of specialized myocardial cells

A. Nodal Cells: Initiate Action Potentials

🔹 Spontaneously depolarize
🔹 Significance: Stimulate Contraction

B. Conducting Cells: Rapidly conduct Action Potentials

🔹 Significance: Effectively distribute Action Potentials
1. **Sino Atrial (SA) Node**: Nodal Cells
   - Location: Superior/Lateral corner of Rt. Atrium
   - Function: **Pacemaker**
     - Initiates: "Pacemaker potentials"
     - Determines contraction rate: Pacing
       ✓ ~ 60 beats per minute

2. **Resulting Events**:
   a. Current spreads across ALL interconnected Atrial Cell
      - **Atrial Myocardium**
      - **Conductance across atrial myocardium**: Gap junctions: 0.5 m/secs

   <0.11 msec
b. Stimulates **Atrial Systole**
c. Important: Current **DOES NOT** spread to
   **Ventricles**
   * Cardiac Skeleton
   * No Gap Junctions

2. **Atrioventricular (AV) Node**: Nodal Cells
   - **Slow** group of Nodal Cells
     * AV node Conductance: 0.05 m/sec
   - Location: Inferior/medial Right Atria
     * Stimulus: Atrial depolarization

   • Functional Significance:
     a. **Slows Electrical current**
        ⇒ **Allows Atria to contract before Ventricles**

   PR Interval: <0.2 sec
3. **Bundle of His (AV Bundle): Conducting Fibers**
   - **Location:** Interventricular Septum (Superior)
   - **Functional Significance:** Carries stimulus through Cardiac Skeleton
     - AV bundle Conductance: 2 m/sec

4. **Bundle Branches (Rt. & Lft.): Conducting Cells**
   - **Location:** Interventricular Septum
   - **Functional Significance:** Divides current to the Right and Left Ventricles
     - Bundle branch Conductance: 2 m/sec

5. **Purkinje Fibers: Conducting Fibers**
   - **Location:** Network throughout Ventricular Myocardium
   - **Functional Significance:** Spreads current quickly through entire Myocardium
     - Purkinje Fiber Conductance: 4 m/sec
Clinical Significance:

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

Cardiac Action Potentials:

- **Pacemaker Cells**: SA Node Cells capable of *spontaneous depolarization*
  - Pacemaker Potentials
  - Nodal Cells NEVER at rest
a. Demonstrate **Automaticity:**

* Internal ability to coordinate contraction rates

b. **Spontaneously Depolarize:** No resting membrane potential

- **CNS control:**
  a. Does NOT initiate contraction
  b. Moderates / adjusts rate
Events of Pacemaker Potentials:

a. Membrane starts at ~ -50 to -60 mV
b. Cells gradually depolarize to ~35 to -50 mV

✓ Depolarization results from opening:

*Na*⁺ / *K*⁺ voltage gated ion channels

Stimulus Voltage: Hyperpolarization from preceding Action Potential

Hyperpolarizing toward -50 to -60 mV

HCN channel:

Hyperpolarization Cyclic Nucleotide channel
c. HCN channels depolarizes to Threshold
   ~35 to ~50mV

d. Voltage Gated Ca\textsuperscript{2+} channels: Opens
   \Rightarrow Rapid depolarization: +10mV

e. Voltage Gated Ca\textsuperscript{2+} channels: Close

f. Voltage Gated K\textsuperscript{+} channels: Open
   \Rightarrow Rapid repolarization / hyperpolarization

g. Return toward –50 to –60mV re-stimulates opening of
   HCN channels
   \Rightarrow Pacemaker potential begins again!
Pacemaker Potentials

- Ca²⁺ channels close; K⁺ channels open
- Action potential
- Ca²⁺ permeability
- K⁺ permeability
- Slow depolarization: Pacemaker potential
- Threshold
- Time (ms)

Autonomic Innervation

- Vagal
- Sympathetic
- Sympathetic nervous system
- Parasympathetic nervous system
- Medulla oblongata
- Sympathetic trunk
- Sympathetic ganglia
- Sympathetic chain

Homeostasis of heart rate

- Vagal
- Sympathetic
- Intrinsic Rate (100-110 bpm)
- 50
- 200
- DC '16
a. Neurotransmitter: Norepinephrine
   - Binds β1 Receptor:
     G protein – Second Messenger
b. Increases concentration of: cAMP
c. cAMP binds: HCN Channels
   - Sensitizes: HCN channels
     - Opens to a greater degree: More charge movement – more permeable
d. Overall Effect: Pacemaker Potentials depolarize more quickly
- Reach threshold faster
- Pace heart faster

Parasympathetic Nervous System:

a. Neurotransmitter: Acetylcholine
   - Binds Muscarinic Receptors: G protein operated ion channel

b. Open K⁺ channels: Increase Potassium Permeability

b. Nodal Cells more resistant to depolarization
   - K⁺ efflux counteracts Na⁺ influx
   - Lengthens “ramp” to threshold
   - Decreases Heart Rate

- 2 heart beats result
- 3 heart beats result
- 1 heart beat results