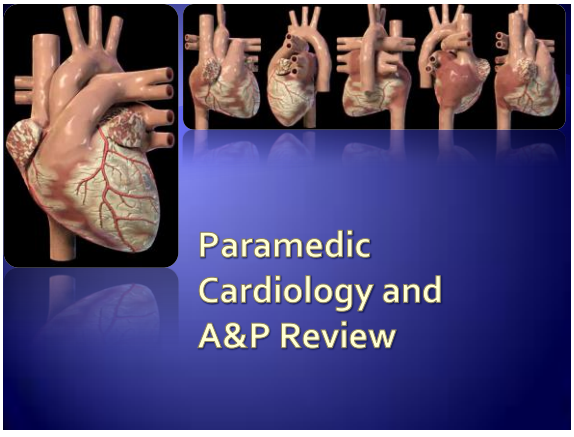
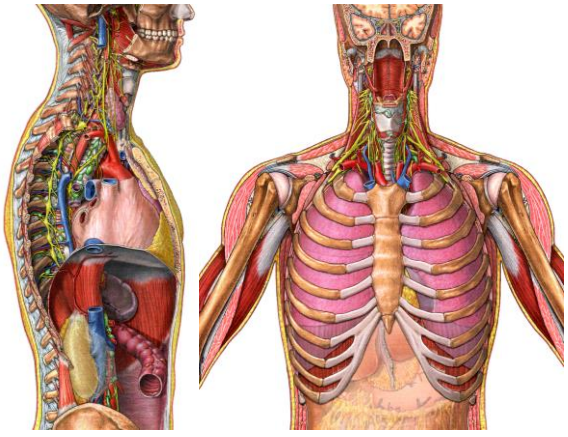
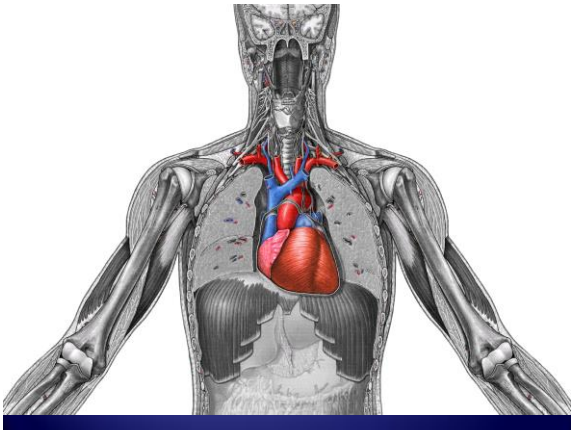
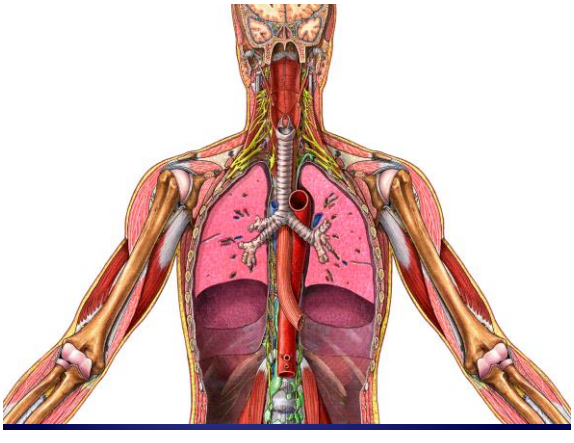








Heart Anatomy

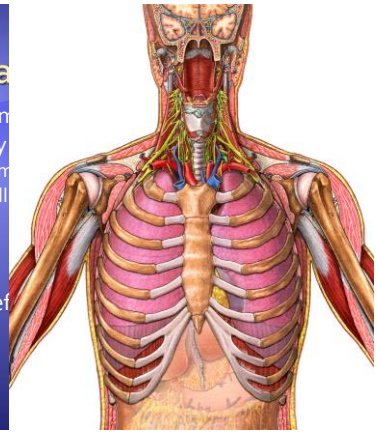
- It beats over 100,000 times a day to pump over 1,800 gallons of blood per day through over 60,000 miles of blood vessels.
- During the average lifetime, the heart pumps nearly 3 billion times, delivering over 50 million gallons of blood!

Heart Anatomy

- Muscular pump
  - Two atria
  - Two ventricles
- Cone shape
  - Top is Base
  - Bottom is Apex
- Size of closed fist
  - 9-12 oz.

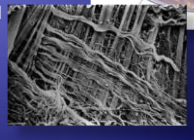
Heart Ana

- In mediastinum thoracic cavity
  - 2/3 of heart's m lies left of midl sternum
- Tilted slightly towards the lef chest



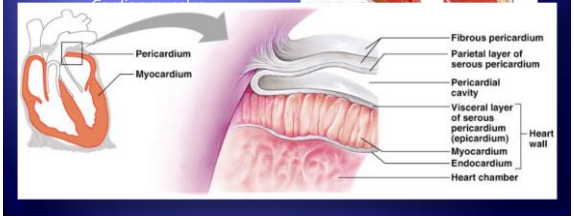
Pericardium

- Fibrous outer layer
- Serous pericardium
  - Parietal layer
    - Beneath the fibrous
  - Visceral layer
    - Attached to epicardium
- Cavity between layers contains pericardial fluid
  - Reduces friction



Heart Wall

- Epicardium
  - "Visceral pericardium"
  - Smooth surface
- Myocardium

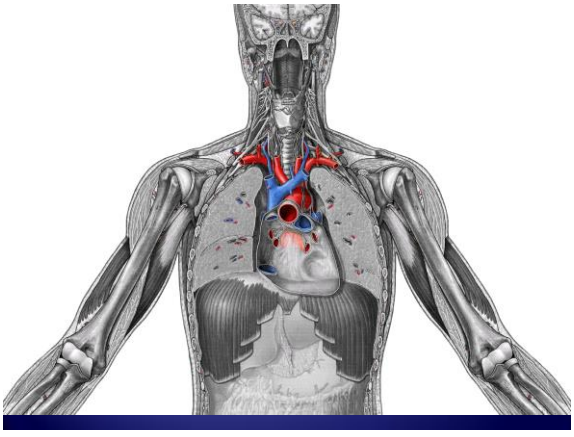


Coronary Vessels

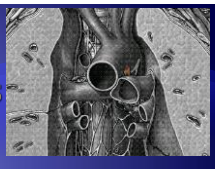
- Seven large veins carry blood to the heart
  - Pulmonary veins (4)
  - Superior and inferior vena cavae (2)
- Coronary sinus (1)

Coronary Vessels

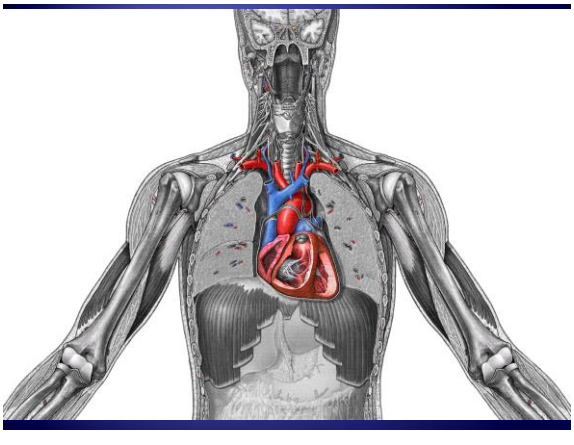
- Aorta
- Pulmonary trunk
- Coronary arteries supply heart muscle



Ductus Arteriosus

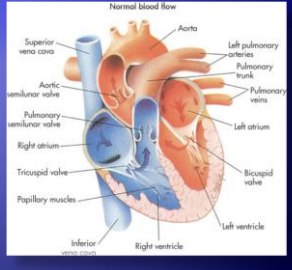


- During Fetal life:
- Connects Pulmonary Trunk with the Aorta
- Diverts blood away from the non-functioning lungs
- Normally closes after birth leaving a remnant known as the ligamentum arteriosum

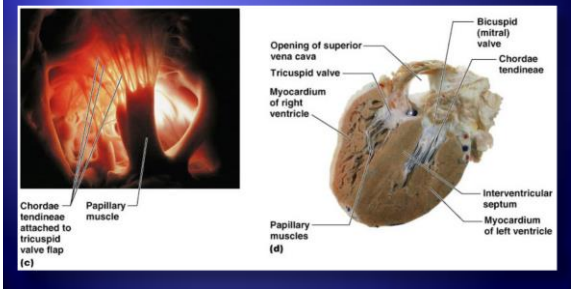


Atrioventricular Valves

- Allow blood flow from atria into ventricles
- Held by chordae tendineae
  - Controlled by papillary muscles
- Prevent backflow
- Tricuspid valve
- Mitral (bicuspid) valve

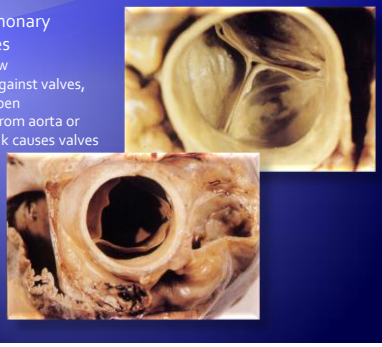


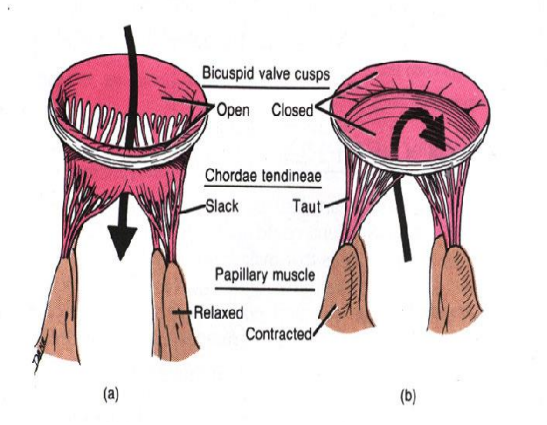
Heart Valves



Semilunar Valves

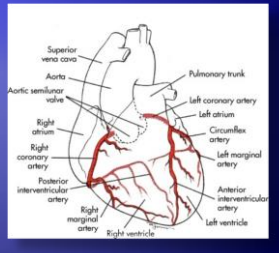
- Aortic and pulmonary semilunar valves
  - Block blood flow
  - Blood pushes against valves, forcing them open
  - Blood flowing from aorta or pulmonary trunk causes valves to close





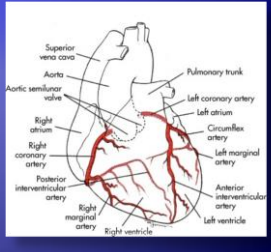
Coronary Arteries

- Supply arterial blood to heart muscle
  - 200-250 mL/min at rest
  - Left coronary artery carries about 85% of blood supply to myocardium
  - Right coronary artery carries remainder
- Originate above aortic valve
  - Most coronary artery perfusion occurs during diastole



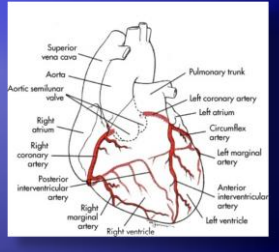
Left Coronary Artery (LCA)

- Divides into left anterior descending and circumflex arteries
  - Left anterior descending (LAD) supplies:
    - Anterior wall of left ventricle
    - Interventricular septum
  - Circumflex supplies (LCX):
    - Lateral and posterior portions of left ventricle
    - Part of right ventricle



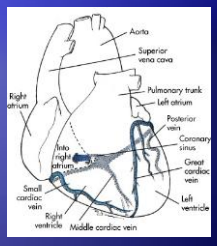
Coronary Arteries

- Right coronary artery and left anterior descending artery supply:
  - Most of right atrium and ventricle
  - Inferior aspect of left ventricle
- Anastomoses provide collateral circulation



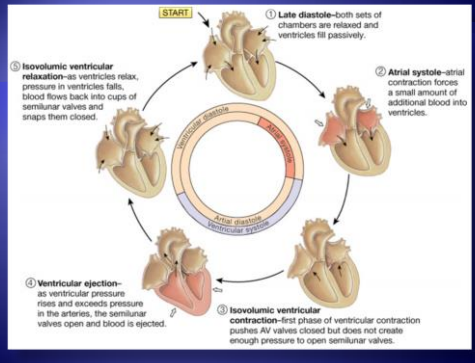
Coronary Capillaries

- Exchange nutrients and metabolic wastes
- Merge to form coronary veins
- Coronary sinus empties into right atrium
  - Major vein draining myocardium

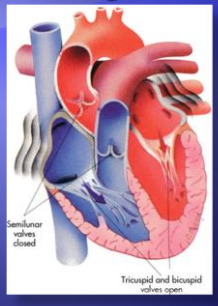


Cardiac Cycle

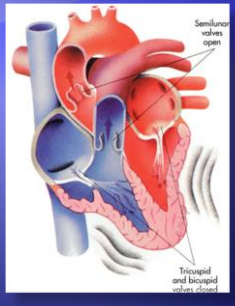
- Actual time sequence between ventricular contraction and relaxation (0.8 seconds)
- Systole (contraction)
  - Lasts about 0.28 seconds
  - Atrial
    - provides only 30% filling of ventricles
  - Ventricular
- Diastole
  - Lasts 0.52 seconds
  - Atrial
  - Ventricular
    - 70% passive filling of ventricles
  - Coronary arteries fill



Heart Action during Atrial Systole



Heart Action during Ventricular Systole

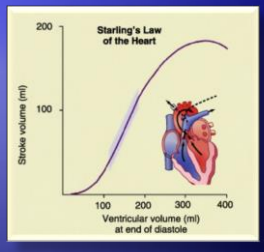


Cardiac Output

- Stroke volume
  - Amount of blood one ventricle pumps in a single contraction
  - 70 mL
- Heart rate
  - Number of contractions in one minute
- Preload
  - End diastolic pressure (EDP)
  - Pressure in ventricles at the end of diastole
  - More important than afterload (ESP) in determining cardiac output

Cardiac Output

- Contractility
  - Determined by preload and inotropics
- Starling's law
  - Myocardial fibers contract more forcefully contract when stretched



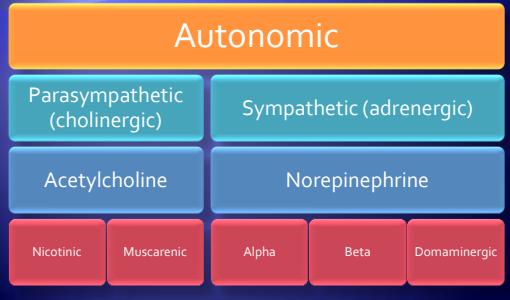
Cardiac Output

- Afterload (ESP)
  - Peripheral vascular resistance
  - Nature of arterioles
- Blood pressure = CO X PVR

Cardiac Output

- Around 5L :
  (72 beats/m × 70 ml/beat = 5040 ml)
- Rate: beats per minute
- Volume: ml per beat
  - EDV - ESV
  - Residual (about 50%)

Nervous System Control of the Heart



Sympathetic Control

- Cardioacceleratory Center
- Sympathetic ganglion
  - Innervates SA node, atria, AV junction, ventricles
- Adrenergic receptor sites

Sympathetic Control

- Norepinephrine
  - Dopaminergic (carotid arteries, renal, mesenteric, visceral blood vessels)
    - Stimulation causes dilation
  - Alpha (skin, cerebral, visceral)
  - Beta 1 (heart)
  - Beta 2 (lungs)

Sympathetic Control

- Postganglionic sympathetic fibers release norepinephrine; have effects on myocardium:
  - Inotropic (force of contractility)
  - Dromotropic (velocity of conduction)
  - Chronotropic (heart rate)

Sympathetic Control

- Sympathetic stimulation of the heart
  - Dilation of coronary blood vessels
  - Constriction of peripheral vessels
  - Increased oxygen demands of the heart met by increase in blood and oxygen supply

Parasympathetic Control

- Cardiac Inhibitory Center (CIC)
  - Vagus nerve (X)
    - Innervates SA node, atria, AV junction
  - Cholinergic receptor sites

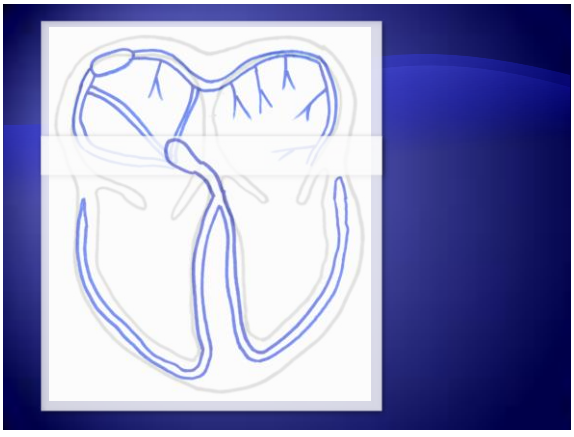
Parasympathetic Control

- Acetylcholine
  - Nicotinic (skeletal muscle)
  - Muscarinic (smooth muscle)
- Slows rate at the SA node
- Slows conduction through AV node
- Decreases strength of atrial contraction
- Small effect on ventricular contraction

Parasympathetic Control

- Parasympathetic innervation of the heart by vagus nerve
  - Continuous inhibitory influence on the heart by decreasing heart rate and contractility

BRIEF ELECTROPHYSIOLOGY REVIEW

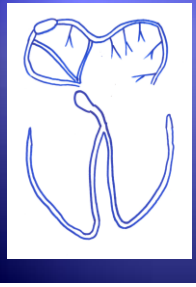


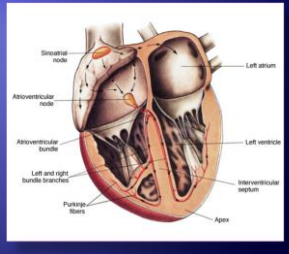
Atrial Conduction
Intrinsic Rate of 60-100

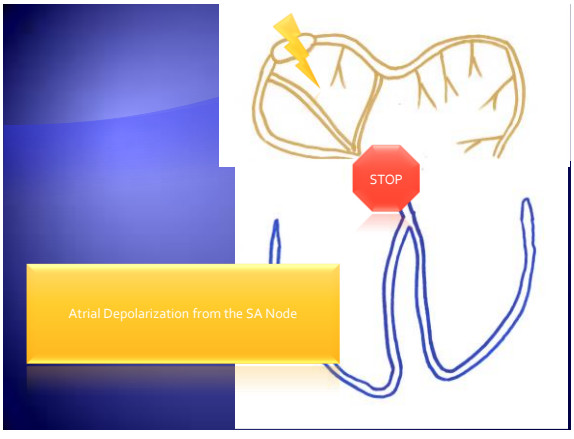
Junctional Conduction
Intrinsic Rate of 40-60

Ventricular Conduction
Intrinsic Rate of 20-40

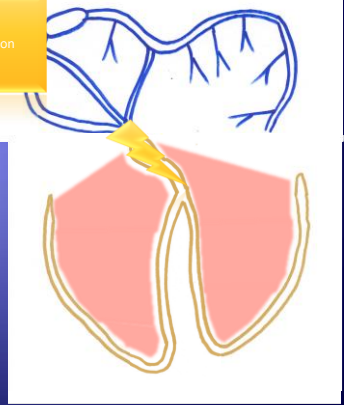
Conduction System of the Heart





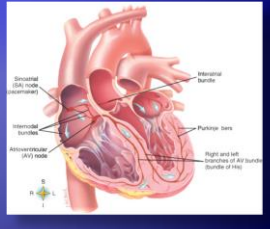


Normal Ventricular Depolarization



Electrical Conduction System

- Sinoatrial node (SA node)
- Atrioventricular (AV) junction
  - AV node
    - Delay 0.15 sec.
  - Bundle of His
- His-Purkinje system
  - Bundle branches
    - Right
    - Left anterior fascicle
    - Left posterior fascicle



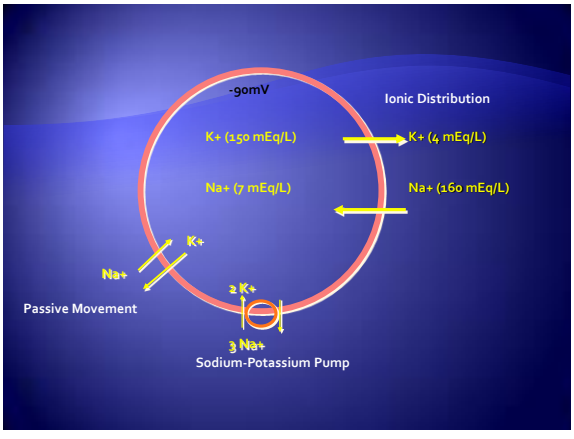
Cardiac Cell Properties

- Automaticity
  - Ability to generate own electrical impulses
  - Pacemaker sites
- Excitability
  - Irritability – ability to respond to impulses
- Conductivity
  - Ability to receive and transmit impulses (syncytium)
- Contractility
  - Rhythmicity – cause contraction in response to stimuli

Ion Concentration

Ion	Extracellular Concentration (mmol/L)	Intracellular Concentration (mmol/L)	Ratio of extracellular to intracellular concentration
Na^+	135 - 145	10	14:1
K^+	3.5 - 5.0	155	1:16
Cl^-	95 - 110	20 - 30	4:1
Ca^{2+}	2	10^{-4} mmol/L	2×10^4

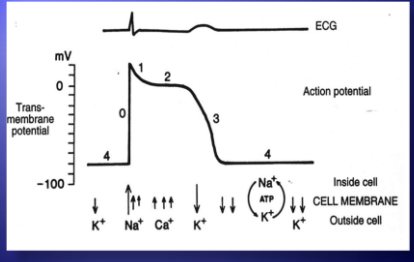
Although intracellular Ca^{2+} content is about 2 mM, most of this is bound or sequestered in intracellular organelles (mitochondria and sarcoplasmic reticulum).



Cardiac Action Potential

- Phase 0 (rapid depolarization phase)
- Phase 1 (early rapid depolarization phase)
- Phase 2 (plateau phase)
- Phase 3 (terminal phase of rapid repolarization)
- Phase 4 (resting period)

Action Potential of Myocardial Cells



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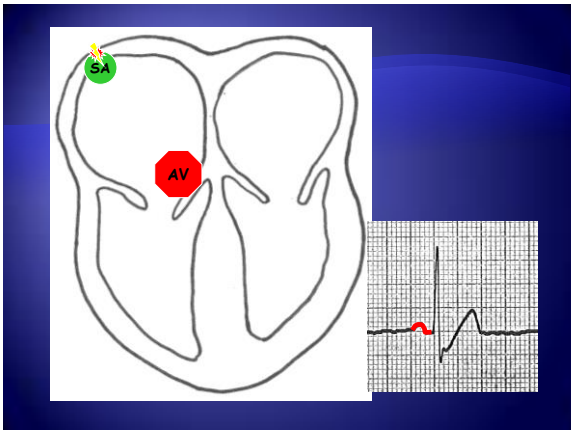
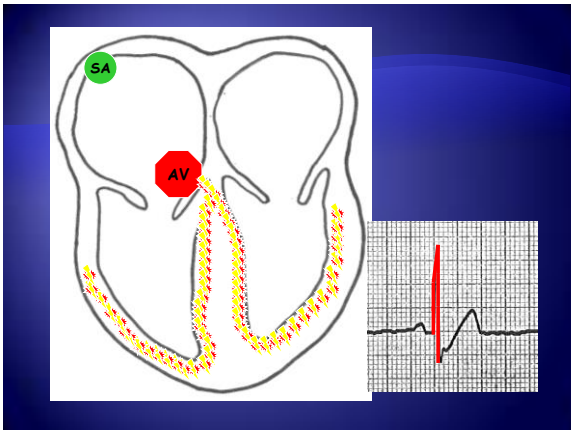
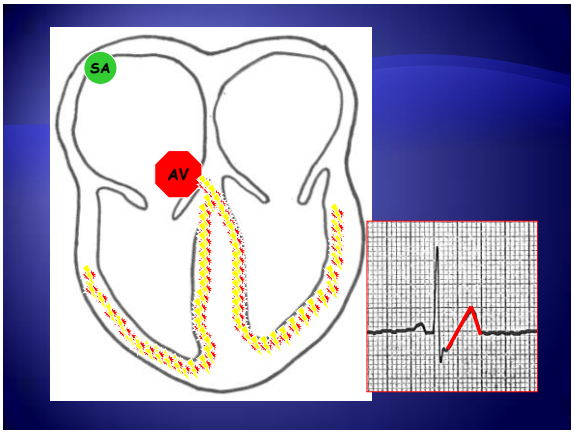
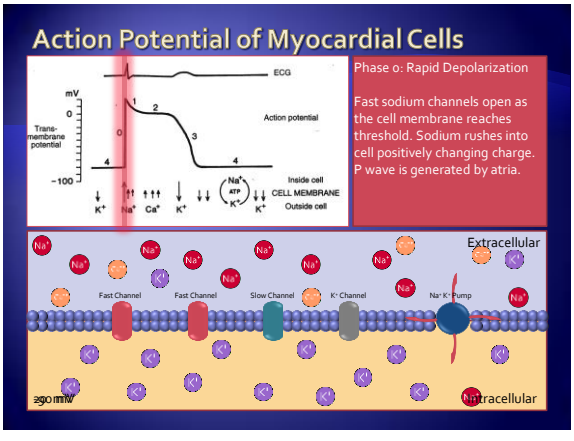
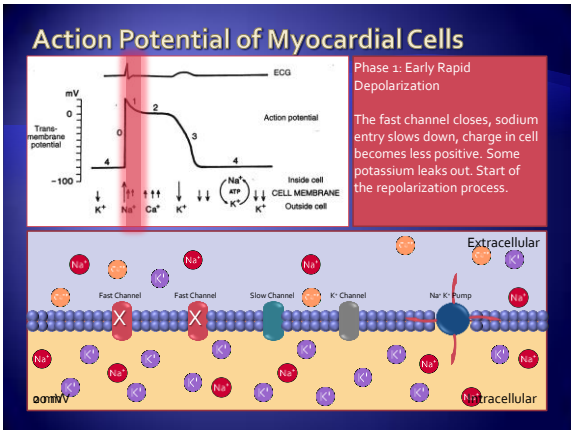
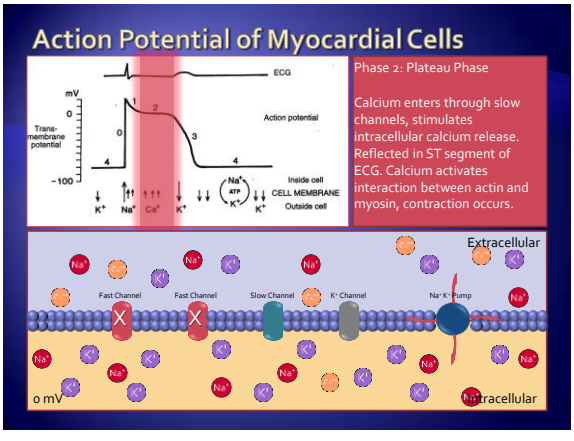

SA
AV


SA
AV

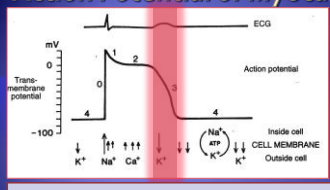

SA
AV


Action Potential of Myocardial Cells
ECG
mV
0
Trans-membrane potential
-100
Action potential
Inside cell
CELL MEMBRANE
Outside cell
Phase 0: Rapid Depolarization
Fast sodium channels open as the cell membrane reaches threshold. Sodium rushes into cell positively changing charge. P wave is generated by atria.
Extracellular
Fast Channel
Fast Channel
Slow Channel
K+ Channel
Na+ K+ Pump
Intracellular


Action Potential of Myocardial Cells
ECG
mV
0
Trans-membrane potential
-100
Action potential
Inside cell
CELL MEMBRANE
Outside cell
Phase 1: Early Rapid Depolarization
The fast channel closes, sodium entry slows down, charge in cell becomes less positive. Some potassium leaks out. Start of the repolarization process.
Extracellular
Fast Channel
Fast Channel
Slow Channel
K+ Channel
Na+ K+ Pump
Intracellular

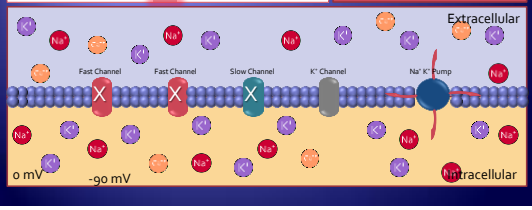

Action Potential of Myocardial Cells
ECG
mV
0
Trans-membrane potential
-100
Action potential
Inside cell
CELL MEMBRANE
Outside cell
Phase 2: Plateau Phase
Calcium enters through slow channels, stimulates intracellular calcium release. Reflected in ST segment of ECG. Calcium activates interaction between actin and myosin, contraction occurs.
Extracellular
Fast Channel
Fast Channel
Slow Channel
K+ Channel
Na+ K+ Pump
o mV
Intracellular

Action Potential of Myocardial Cells

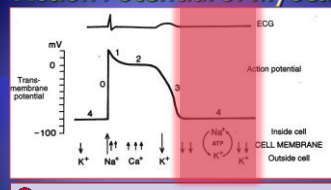


Phase 3: Final Rapid Repolarization

Slow channels close. Sodium and calcium stop entering cell. Potassium quickly moves out of the cell. Represented by the T wave.

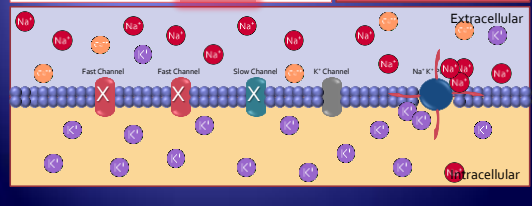


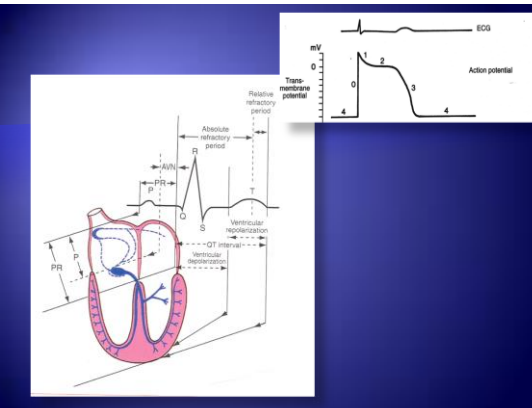
Action Potential of Myocardial Cells



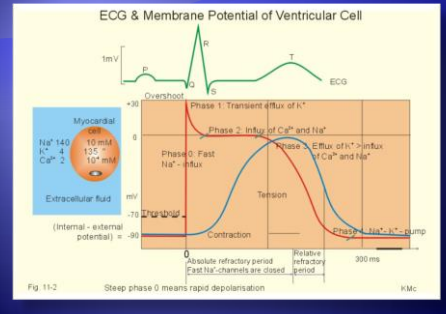
Phase 4: RMP

Sodium/potassium pump moves sodium from the inside to outside, moves potassium from outside to inside.



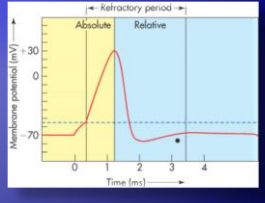


Action Potential of Myocardial Cells



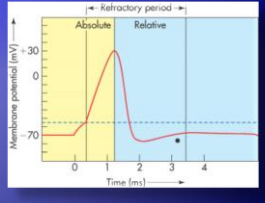
Absolute Refractory Period

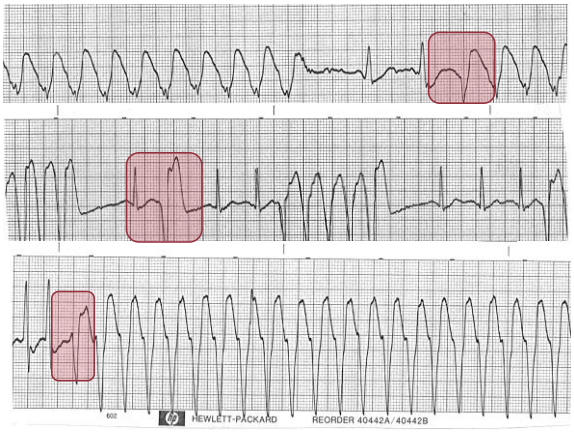
- Absolute refractory period
  - Cardiac muscle cell is completely insensitive to stimulation
- Refractory period of ventricles is about same duration as action potential



Relative Refractory Period

- Muscle cell is more difficult than normal to excite but can still be stimulated




HEWLETT-PACKARD
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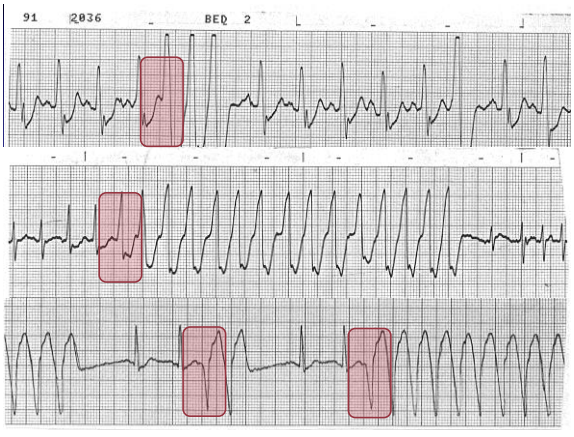
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QUESTIONS?