

Cardiovascular Physiology

Gems of Wisdom

Objectives

- Review the basic anatomy and physiology of the cardiovascular system.
- Describe the electrical and mechanical events involved in the cardiac cycle.

Objectives

- Discuss the factors that alter or impact the electrical and mechanical events of the cardiac cycle.
- Explain the physiology of circulation and perfusion, including the following components:
 - Cardiac output
 - Blood pressure
 - Feedback loops
 - Capillary sphincters

Cardiovascular System Review

Review of Cardiovascular Anatomy and Physiology: The Heart

Anatomy Review

- Right atrium
Incoming blood supply
- Tricuspid valve
Chordae tendinae and papillary muscles
- Right Ventricle
Pulmonary artery



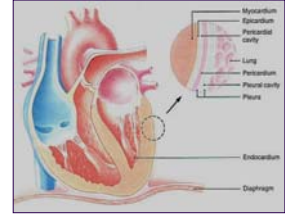
Anatomy Review

- Left atrium
Receives supply from the pulmonary vein
- Left ventricle
- Bicuspid valve
Also known as the mitral valve
- Aorta



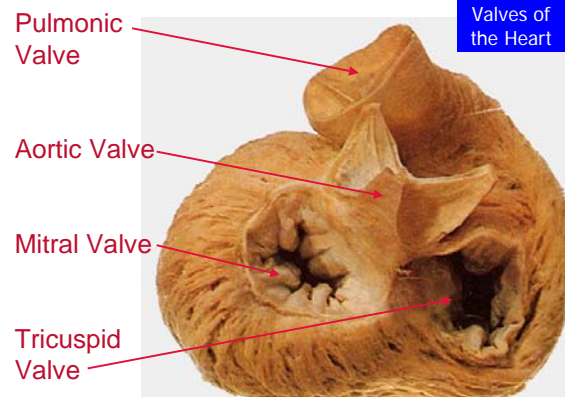
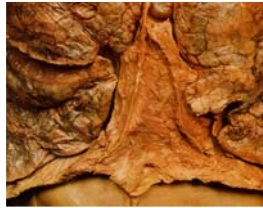
Anatomy Review

- Heart wall
 - Endocardium
 - Myocardium
 - Epicardium
 - Splits into another outside layer – the pericardium

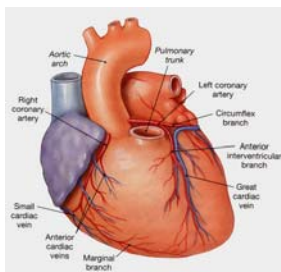


The Pericardium

- Fixates the heart to the thoracic cavity
- Relatively inflexible tissue
- Holds 30-50mL of serous fluid between the pericardium and epicardium
 - Pericardial sac
 - Prevents friction during contraction

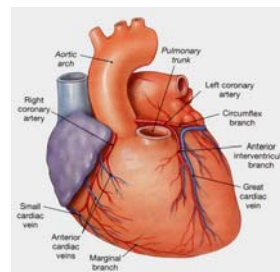


Coronary Artery Supplies



- Right C.A.
 - Right atrium and ventricle
 - Inferior portion of the left ventricle
 - Interventricular septum
 - Conduction system

Coronary Artery Supplies



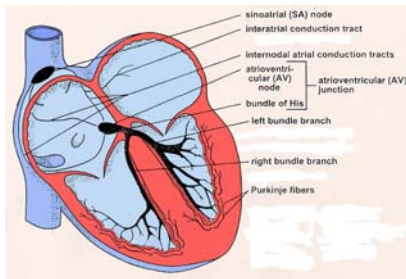
- Left C.A.
 - Left atrium
 - Nearly all of the left ventricle
 - AV node in half of the population

Review of Cardiovascular Physiology

Physiology of the Heart

- Electrical components
 - Electrophysiology
 - The Cardiac Cycle
- Mechanical Events of the Cardiac Cycle
- Influences of Electrical and Mechanical Heart Function

Electrical Conduction System



Cardiac Cell Types

- **Electrical cells**
 - Generate and conduct impulses rapidly
 - SA and AV nodes
 - Nodal pathways
 - Interventricular septum
 - No contractile properties
- **Muscle (myocardial) cells**
 - Main function is contraction
 - Atrial muscle
 - Ventricular muscle
 - Able to conduct electrical impulses
 - May generate its own impulses with certain types of stimuli

Unique Properties of Cardiac Cells

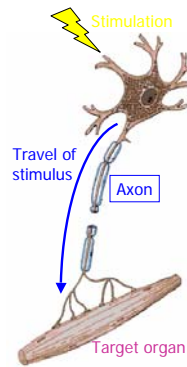
- **Automaticity**
 - SA and AV nodes
- **Excitability**
 - All cells
 - Points of stimulation
 - Nervous system
 - Physical cell damage
 - Ischemia
 - Electrolytes
- **Conductivity**
 - All cells
 - Points of stimulation
 - Nervous system
 - Electrolytes
 - Slowing of conductivity
 - Ischemia
 - Calcification of nodal pathways
- **Contraction**
 - Muscle cells

Electrophysiology of the Heart



Review of nerve transmission

- Path of travel
 - Stimulation of the nerve
 - Travel of stimulus down the axon
 - "Wave effect" of stimulus down the axon is caused by the rapid movement of ions across the cell membrane of the axon
 - Impulse moves across synapse to another nerve or to a target organ



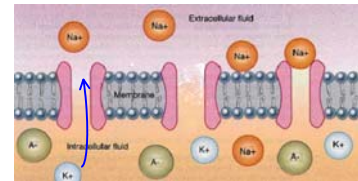
Nerve impulse Terminology

- Resting state
 - The relative electrical charges found on each side of the membrane at rest
 - Net positive charge on the outside
 - Net negative charge on the inside
- Action Potential
 - Change in the electrical charge caused by stimulation of a neuron

Action Potential Terms

- Depolarization
 - The sudden reversal of electrical charges across the neuron membrane, causing the transmission of an impulse
 - Minimum voltage must be met in order to do this
- Repolarization
 - Return of electrical charges to their original resting state

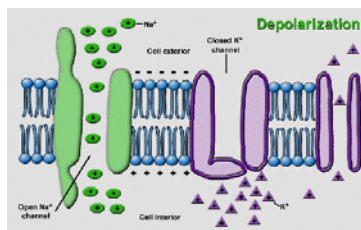
Action Potential – Resting State



- Sodium stays outside of the cell
 - The pores in the membrane are too small for them to pass through
- Potassium mostly stays inside
- Massively negative charges never leave the cell

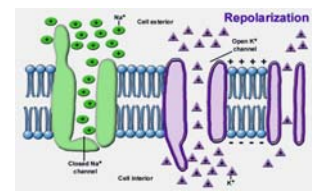
Action Potential - Depolarization

- The stimulus hits the cell
- Sodium channels open up and sodium pours in
- The charges reverse
 - Positive inside
 - Negative outside



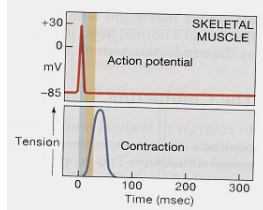
Action Potential - Repolarization

- Sodium channels close
- Potassium channels open
 - Potassium pours out
 - Allows for a quick return to a resting state
- Sodium is kicked out of the cell
 - Active transport
 - Sodium-potassium pump



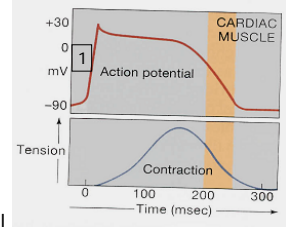
The Action Potential in Skeletal Muscle

- The electrical events occurring at the cell will always preclude the actual muscle contraction
- The action potential is quick to allow for a faster contraction of the muscle



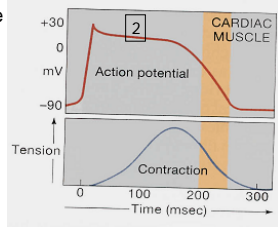
The Action Potential in Cardiac Muscle: Step 1

- The conduction cells stimulate the myocardial cells
- Similar events of depolarization
 - Sodium dumps inward
 - Potassium rushes out
 - Sharp spike of the initial action potential



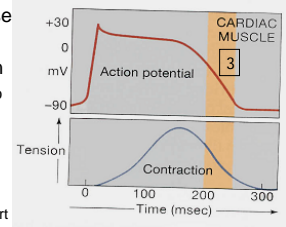
The Action Potential in Cardiac Muscle: Step 2

- The sodium channels close
- Calcium channels open slowly
 - Calcium trickles into the cell
 - Allows for a stronger contraction
 - Allows all of the ventricular cells to contract together
- Potassium movement is minimal

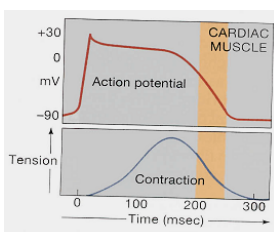


The Action Potential in Cardiac Muscle: Step 3

- The calcium channels close up
- Potassium channels widen
 - Rush of potassium back into the cell
 - Slower return to a complete resting state
 - Allows for contraction to finish and to get the ventricular chambers to start filling with blood

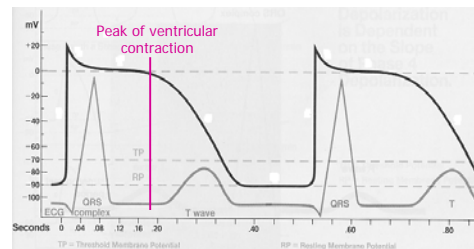


Action Potential Term: Refractory Period



- Absolute**
A period of time where the action potential is resistant to any additional stimuli
 - Steps 1, 2 and the early part of step 3
- Relative**
A period of time where the action potential moderately resists a stimulus
Highlighted area

Electrical and Mechanical Connections



Mechanical Function of the Heart

The Cardiac Cycle

- 2 components
 - Diastole
 - Filling of the chamber
 - Systole
 - Contraction of the chamber and ejection of blood

Cardiac Output

- The amount of blood ejected from the ventricle in one minute
- Elements of cardiac output
 - Stroke volume
 - Amount of blood ejected from the ventricle in one contraction
 - Heart rate
 - The # of cardiac cycles in one minute

$$CO = SV \times HR$$

$$CO = SV \times HR$$

Determination of Stroke Volume

- Preload
 - Amount of blood delivered to the chamber
 - Depend upon venous return to the heart
 - Also dependent upon the amount of blood delivered to the ventricle by the atrium
- Contractility
 - The efficiency and strength of contraction
 - Frank Starling's Law
- Afterload
 - Resistance to forward blood flow by the vessel walls

Another way to look at cardiac output



Factors Affecting the Cardiac Cycle

Cardiac Feedback Loops

- Master controller: the medulla

Incoming input

- Chemoreceptors
Sense changes in pH, PaCO₂ and PaO₂
- Baroreceptors
Sense changes in arterial pressure

Response of the medulla

- Stimulate the autonomic nervous system

Autonomic Nervous System

- Sympathetic Nervous System

Extensively innervates the SA node and ventricular cells

- Increase in heart rate
- Increase in conduction and contractility in the ventricles

- Parasympathetic Nervous System

Innervates the SA and AV nodes

- Decreases heart rate
- Decreases conduction times through the AV node

Chemical Factors

- Hormones

Epinephrine

- Stimulation of beta receptors in the myocardium
- Increase in contractility of the ventricles
- Increase in conduction throughout the ventricles

Chemical Factors

- Electrolyte Concentrations

Calcium

- Impacts the strength of contractions
- High calcium may cause irritability of electrical cells

Chemical Factors

- Potassium

Impacts the rates of firing and recovery of the cardiac cells

High potassium

- Irregular firing of cardiac cells
- Dysrhythmias and ventricular fibrillation potentials

Low potassium

- Longer delays in the firing of cardiac cells
- May be caused by diuretic use
Bradycardia
Hypotension (systemic complication)
Poor cardiac output results

The pieces *will* fit together soon....

