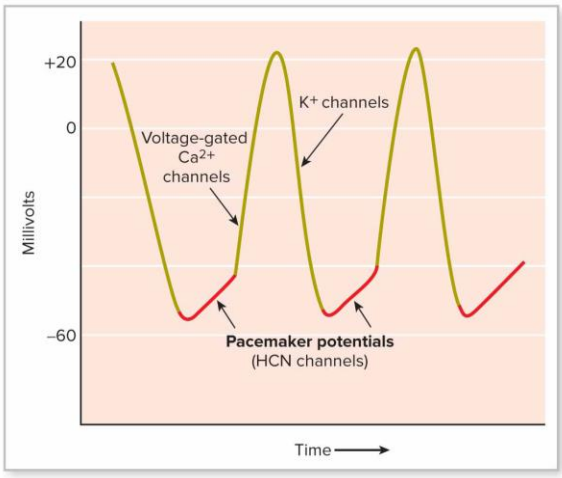
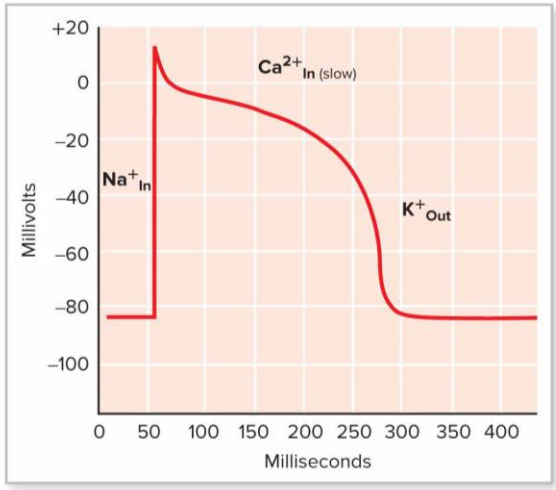
Topic 22: Cardiovascular Part 2: Electrical Activity and Cardiac Output: Study Guide

Electrical Activity of the Heart and the Electrocardiogram

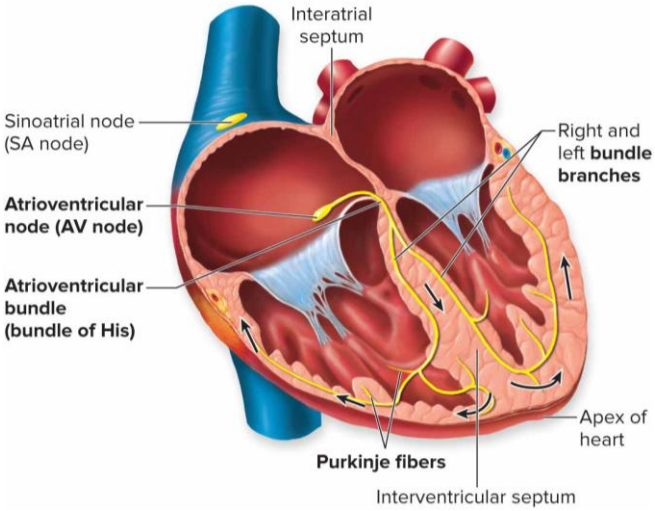


- Cardiac muscle cells are interconnected by _____ junctions called intercalated discs.
- Once stimulation is applied, the impulse flows from cell to cell.
- The area of the heart that contracts from one stimulation event is called a myocardium or functional syncytium.
- The atria and ventricles are separated electrically by the _____ skeleton.
- Automaticity – automatic nature of the heartbeat
- Sinoatrial node (SA node) - "pacemaker"; located in right atrium
- _____ node and Purkinje fibers are secondary pacemakers or ectopic pacemakers; slower rate than the "normal sinus rhythm"



Pacemaker potential

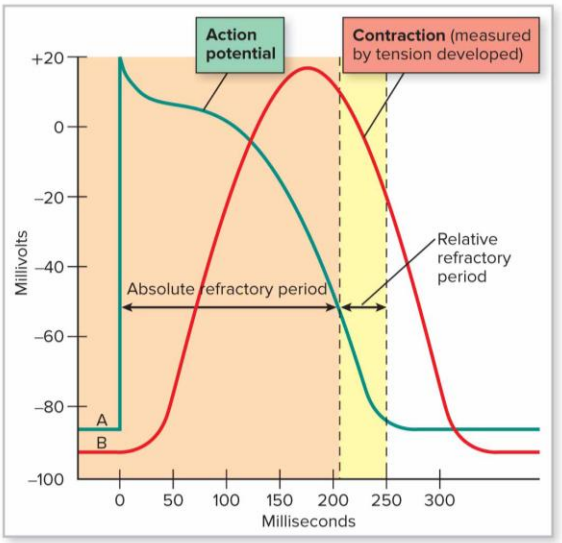
- A slow, spontaneous depolarization; also called diastolic depolarization – between heartbeats, triggered by hyperpolarization
- _____ (hyperpolarization cyclic nucleotide) channels open in response to hyperpolarization and allow Na+ to enter to produce depolarization (called a "funny current")
  - Also open to cAMP in response to beta-adrenergic receptors by epinephrine and norepinephrine
  - At _____mV, voltage-gated Ca2+ channels open, triggering action potential and contraction.
    - Stimulates opening of Ca2+ release channels from the SR
    - Large increase in Ca2+ causes contraction
- Repolarization occurs with the opening of voltage-gated K+ channels.
- Pacemaker cells in the sinoatrial node depolarize spontaneously, but the rate at which they do so can be modulated:
  - Epinephrine and norepinephrine increase the production of cAMP, which keeps cardiac pacemaker channels open.
    - Opens HCN channels for Na+ inflow
    - Speeds heart rate and increases strength of contraction
  - Parasympathetic neurons secrete acetylcholine, which opens K+ channels to slow the heart rate.



Myocardial action potentials

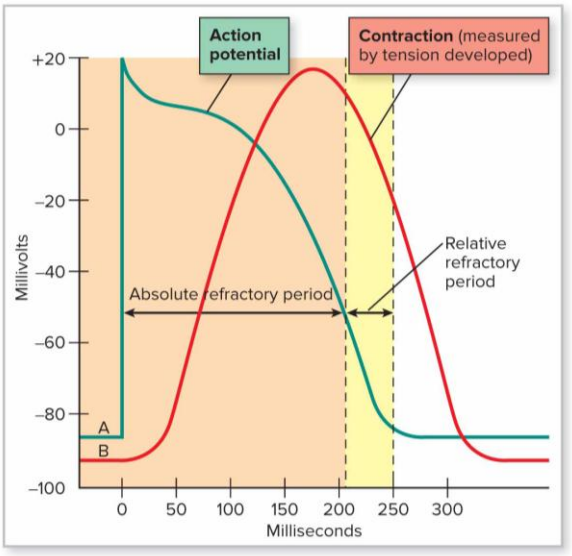
- Cardiac muscle cells have a resting potential of ____mV.
- They are depolarized to threshold by action potentials from the SA node.
- Voltage-gated Na+ channels (fast Na+) open, and membrane potential plateaus at -15mV for 200 to 300 msec.

- Due to balance between slow influx of Ca2+ and efflux of K+
- More K+ are opened, and repolarization occurs.
- Long plateau prevents summation and tetanus
- Conducting tissues of the heart
  - Action potentials spread via _____ discs (gap junctions) between right and left atria.
  - SA node to AV node to stimulate atrial contraction
  - AV node at base of right atrium and bundle of His (AV bundle) conduct toward the ventricles
  - In the interventricular septum, the bundle of His divides into right and left bundle branches
  - Branch bundles become Purkinje fibers, which stimulate ventricular contraction upward



Conduction of Impulses

- Action potentials from the _____ node spread rapidly
  - 0.8 to 1.0 meters/second
- At the _____ node, things slow down.
  - 0.03 to 0.05 m/sec
  - This accounts for half of the time delay between atrial and ventricular contraction.
- The speed picks up in the bundle of His, reaching 5 m/sec in the Purkinje fibers.
- Ventricles contract 0.1 to 0.2 seconds after atria.



Excitation-Contraction Coupling

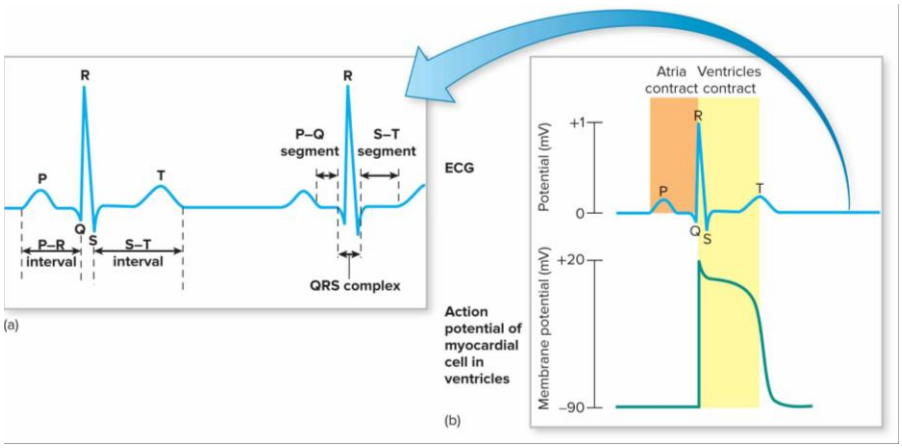
- Ca2+-stimulated Ca2+ release
- Action potentials conducted along the sarcolemma and T tubules, open voltage-gated Ca2+ channels
- Ca2+ diffuses into cells and stimulates the opening of calcium release channels of the SR
- Ca2+ (mostly from SR) binds to troponin to stimulate contraction
- These events occur at signaling complexes on the sarcolemma where it is close to the SR

Repolarization

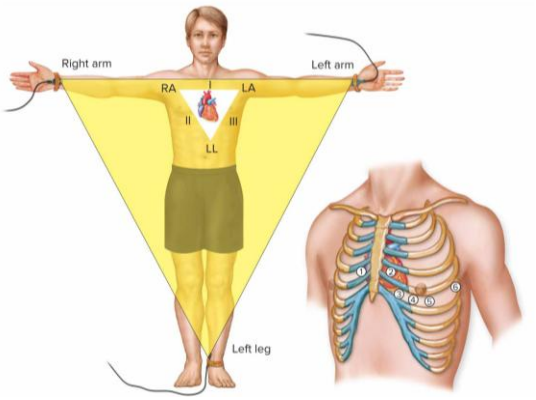
- Ca2+ concentration in cytoplasm reduced by active transport back into the SR by the SERCA pump
- Extrusion of Ca2+ through the plasma membrane by the Na+-Ca2+ exchanger (NCX) – secondary active transport
- Primary active transport of Ca2+ATPase pump
- Myocardium relaxes

Refractory Periods

- Because the atria and ventricles contract as single units, they cannot sustain a contraction.



- Because the action potential of cardiac cells is long, they also have long refractory periods before they can contract again.

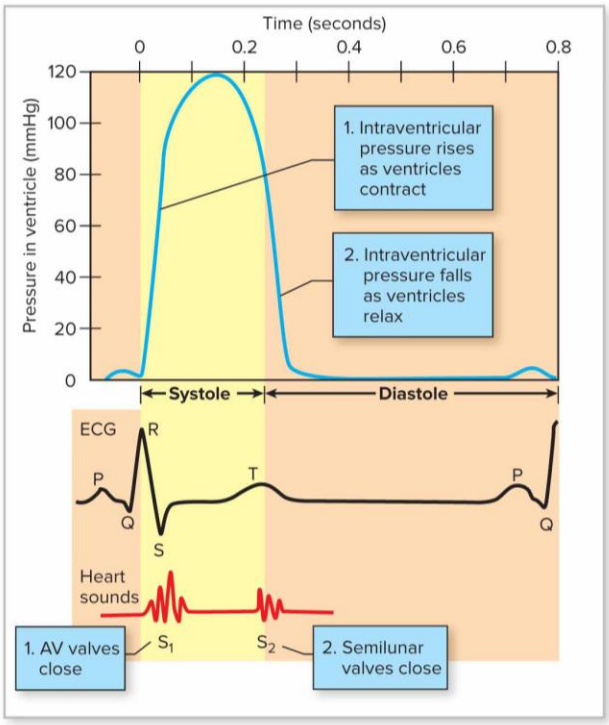


Electrocardiogram (ECG or EKG)

- The electrocardiograph records the electrical activity of the heart by picking up the movement of ions in body tissues in response to this activity.
    - Does _____ record action potentials, but results from waves of depolarization
    - Does not record contraction or relaxation, but the electrical events leading to contraction and relaxation

Electrocardiogram waves and intervals

- P wave - atrial depolarization
- P-Q interval – atrial systole
- QRS wave - ventricular depolarization
- S-T segment - plateau phase, ventricular systole
- T wave - ventricular repolarization
- Electrocardiogram



Electrocardiograph leads

- Bipolar limb leads record voltage between electrodes placed on wrists and legs.
    - Lead I: between right arm and right leg
    - Lead II: between right arm and left leg
    - Lead III: between left arm and left leg
- Unipolar leads record voltage between a single electrode on the body and one built into the machine (ground).
    - Limb leads go on the right arm (AVR), left arm (AVL), and left leg (AVF).
    - There are six chest leads.

ECG and Heart Sounds

- "_____" occurs after the QRS wave as the AV valves close
- "_____" occurs at the beginning of the T wave as the SL valves close

Arrhythmias

- Arrhythmias are abnormal patterns of electrical activity that result in abnormalities of the heartbeat.
- Drugs used to treat arrhythmias affect the nature and conduction of cardiac action potentials, and have been classified into four different groups:
    - Group 1: drugs that block the fast Na+ channels (quinidine, procainamide, lidocaine).
    - Group 2: drugs are beta-blockers (propranolol, atenolol)
    - Group 3: drugs block K+ channels (amiodarone)
    - Group 4: drugs block the slow Ca2+ channels (verapamil, diltiazem).

Blood Vessels: Introduction to Blood Vessels

Types of blood vessels

- Arteries, Arterioles, Capillaries, Venules, Veins

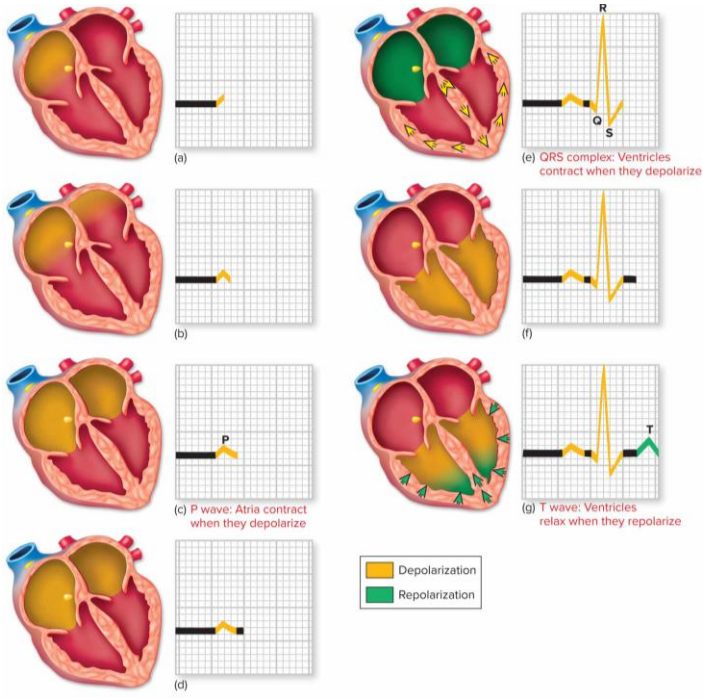
Tunics of blood vessels

- Tunica _____ - inner layer; composed of simple squamous endothelium on a basement membrane and elastic fibers

- Tunica media - middle layer; composed of smooth muscle tissue
- Tunica externa - outer layer; composed of connective tissue

Arteries

- _____ arteries: closer to the heart; allow stretch as blood is pumped into them and recoil when ventricles relax
- Muscular arteries: farther from the heart; have more smooth muscle in proportion to diameter; also have more resistance due to smaller lumina
- Arterioles: 20 to 30 µm in diameter; provide the greatest resistance; control blood flow through the capillaries through vasoconstriction and vasodilation

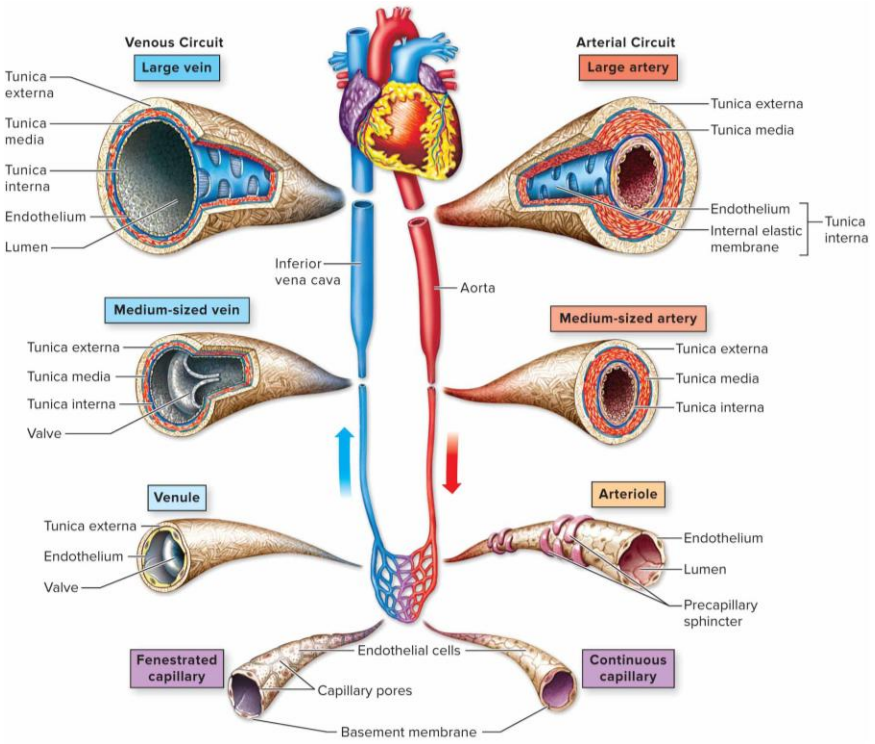


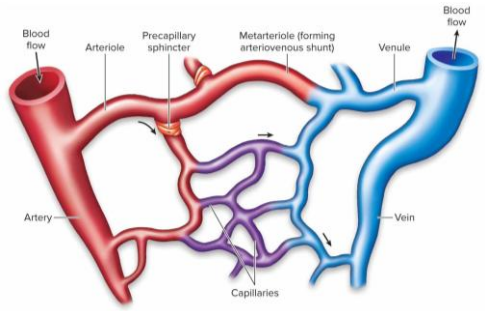
Aneurysm

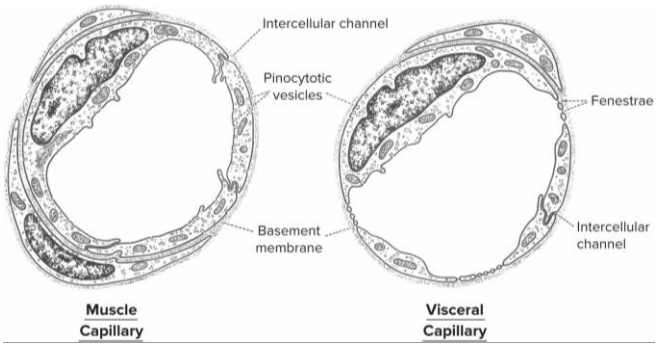
- An _____ is a balloon-like swelling in an artery or in a weakened ventricular wall.
- It most commonly occurs in the aorta—either as a thoracic aortic aneurysm or an abdominal aortic aneurysm, but can occur in cerebral and other arteries.
- A dissected aorta is a tear in the wall of the aortic aneurysm, which often can be detected and corrected before it completely bursts.
- Aneurysms may result from congenital causes and atherosclerosis, but conditions such as hypertension and diabetes can increase the risk.

Capillaries

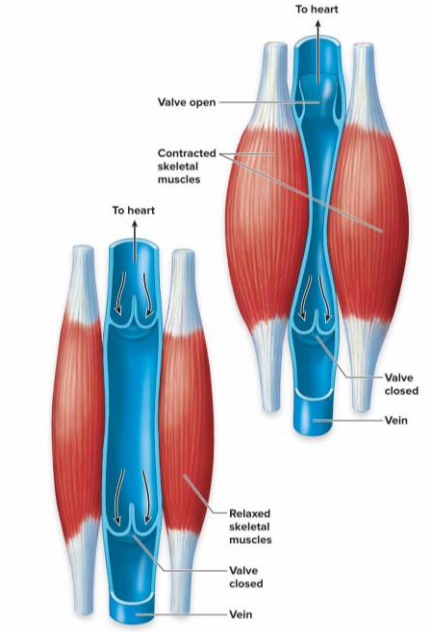
- _____ blood vessel: 7 to 10 µm in diameter
- Single layer of simple squamous epithelium tissue in wall
- Where gases and nutrients are exchanged between the blood and tissues







- Blood flow to capillaries is regulated by:
    - Vasoconstriction and vasodilation of arterioles
    - Precapillary sphincters
- Types of Capillaries
    - Continuous capillaries: Adjacent cells are close together; found in muscles, adipose tissue, and central nervous system (add to blood-brain barrier due to no channels)
    - Fenestrated capillaries: have pores in vessel wall; found in kidneys, intestines, and endocrine glands
    - Discontinuous: have gaps between cells; found in bone marrow, liver, and spleen; allow the passage of proteins

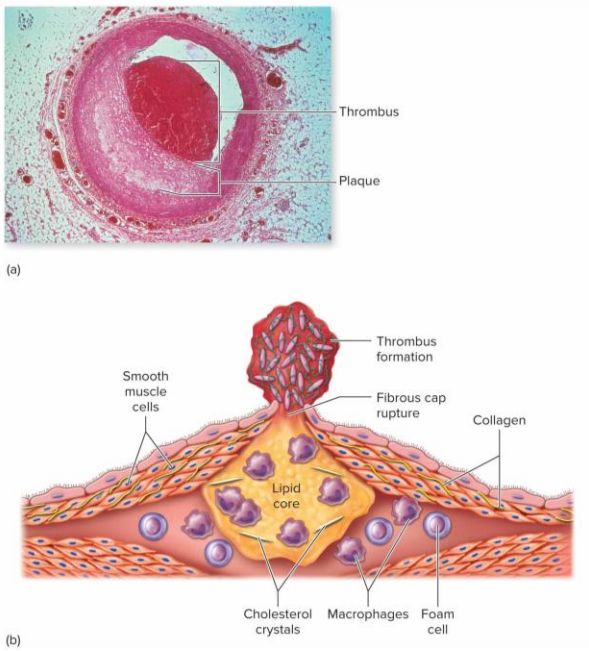


Veins

- Most of the total blood volume is in _____
- Lower pressure (2 mmHg compared to 100 mmHg average arterial pressure)
- Thinner walls than arteries, larger lumen; collapse when cut
- Need help to return blood to the heart:
    - Skeletal muscle pumps: Muscles surrounding the veins help pump blood.
    - Venous valves: Ensure one-directional flow of blood
    - Breathing: Flattening of the diaphragm at inhalation increases abdominal cavity pressure in relation to thoracic pressure and moves blood toward heart.

Varicose Veins

- Varicose veins are enlarged surface veins, generally in the lower limbs, which occur when venous congestion stretches the veins to the point that the venous valves no longer close effectively.
- Genetic susceptibility, occupations that require long periods of standing, obesity, age, and pregnancy (due to compression of abdominal veins by the fetus) are risk factors.
- Walking can reduce venous congestion, as can compression stockings and leg elevation.
- Surgical treatments of varicose veins include sclerotherapy laser therapy, ligation and stripping.



Deep Vein Thrombosis (DVT)

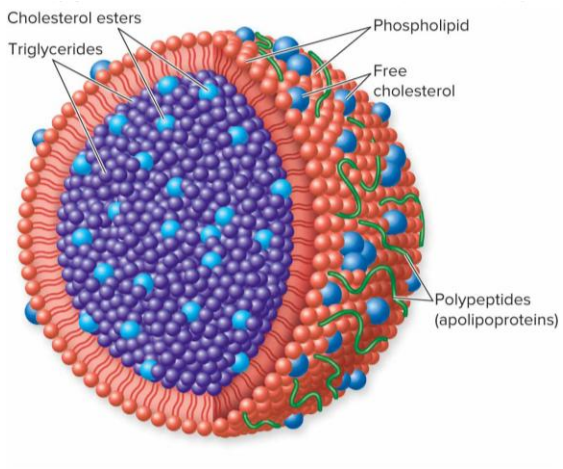
- Inadequate venous flow in a bedridden patient increases the risk of deep vein thrombosis which a can lead to a venous thromboembolism (a traveling blood clot).
- Walking around as soon as possible after a surgery reduces the risk, as does the use of compression stockings and devices that compress the leg.
- Anticoagulant drugs or thrombolytic agents may sometimes be necessary to prevent or treat a thromboembolism so that it doesn't result in a potentially fatal pulmonary embolism.

Atherosclerosis and Cardiac Arrhythmias

Atherosclerosis

- Most common form of arteriosclerosis (_____ of the arteries)
    - Contributes to 31% of the deaths due to heart attack and stroke

    - Plaques protrude into the lumen and reduce blood flow.
    - Serve as sites for thrombus formation
    - Plaques form in response to damage done to the endothelium of a blood vessel.
    - Caused by smoking, high blood pressure, diabetes, high cholesterol



- Developing Atherosclerosis
    - Lipid-filled macrophages and lymphocytes assemble at the site of damage within the tunica interna (fatty streaks).
    - Next, layers of smooth muscle and macrophages are added.
    - Finally, a cap of connective tissue covers the layers of smooth muscle, lipids, and cellular debris – fibrous plaques
    - Progress promoted by inflammation stimulated by cytokines and other paracrine regulators.
- Cholesterol and Lipoproteins
    - Low-density lipoproteins (LDLs) carry cholesterol to arteries.
    - People who consume or produce a lot of cholesterol have more LDLs.
    - This high LDL level is associated with increased development of atherosclerosis
    - The uptake of apolipoprotein B, a type of LDL, into the subendothelial connective tissue of an artery is believed to initiate the formation of the plaque through the formation of foam cell
    - High-density lipoproteins (HDLs) carry cholesterol away from the arteries to the liver for metabolism.
        - This takes cholesterol away from the macrophages in developing plaques (foam cells).
        - Statin drugs (for example, Lipitor) increase HDL levels by allowing the liver to engulf more LDL-cholesterol from the blood

Inflammation in Atherosclerosis

- Atherosclerosis is now believed to be an inflammatory disease.
- _____-reactive protein (a measure of inflammation) is a better predictor for atherosclerosis than LDL levels.
- When endothelial cells engulf LDLs, they become oxidized LDLs that damage the endothelium
- Antioxidants may be future treatments for this condition.

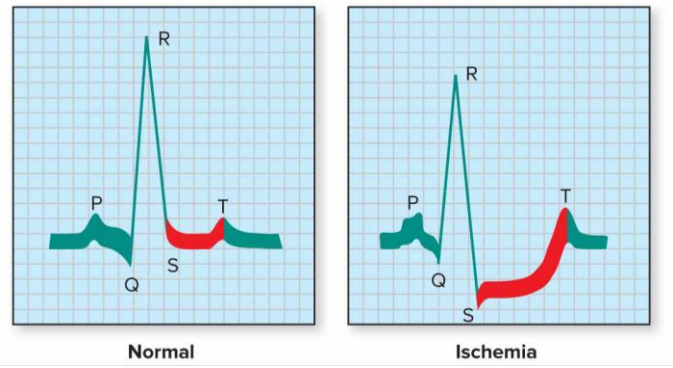
Ischemic Heart Disease

- Ischemia is a condition characterized by inadequate _____ due to reduced blood flow.
    - Atherosclerosis of the coronary arteries is the most common cause.
    - Associated with increased production of lactic acid and resulting pain, called angina pectoris (referred pain).
    - Eventually, necrosis of some areas of the heart occurs, leading to a myocardial infarction (heart attack or MI).
    - Nitroglycerin produces vasodilation that improves blood flow
    - Dead myocardial cells can not be replaced by mitosis of neighboring cells
    - Reperfusion injury may cause death of neighboring cells to enlarge the infarct

Detecting Ischemia

- Depression of the _____ segment of an electrocardiogram; totally occluded vessels will show an elevated S-T segment
- Plasma concentration of blood enzymes
    - Creatine phosphokinase – 3 to 6 hours, return to normal in 3 days

- Lactate dehydrogenase – 48 to 72 hours, elevated about 11 days
- Troponin I – today's most sensitive test; released from damaged myocardial cells

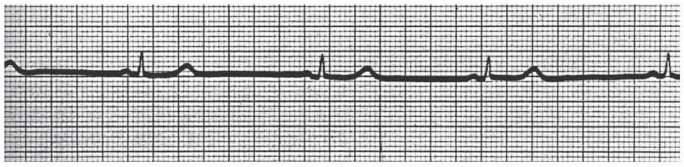


Cerebrovascular Accident (_____)

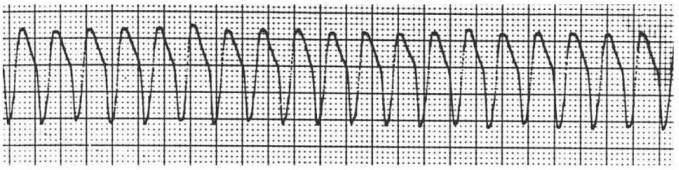
- Second leading cause of death world-wide
- Ischemic stroke – blockage of a cerebral artery by a thrombus usually the result of atherosclerosis
- Hemorrhagic stroke – bleeding from a cerebral artery usually caused by an aneurism
- Risk factors include hypertension, atrial fibrillation, high blood cholesterol, and diabetes
- Excitotoxicity caused by neuron death due to glutamate removal from synapses

Heart Arrhythmias Detected by ECG

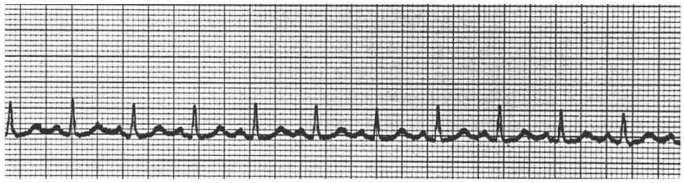
- Abnormal heart rhythms
  - Bradycardia: _____ heart rate, below 60 bpm
  - Tachycardia: _____ heart rate, above 100 bpm
  - These heart rhythms are normal if the person is active, but not normal at rest.
  - Abnormal tachycardia can occur due to drugs or fast ectopic pacemakers.
  - Ventricular tachycardia occurs when pacemakers in the ventricles make them contract out of synch with the atria.
    - This condition is very dangerous and can lead to ventricular fibrillation and sudden death.
  - Paroxysmal supraventricular tachycardia (_____) – sporadic tachycardia that originates in the atria and produces a fast ventricular rate; treated with intravenous adenosine



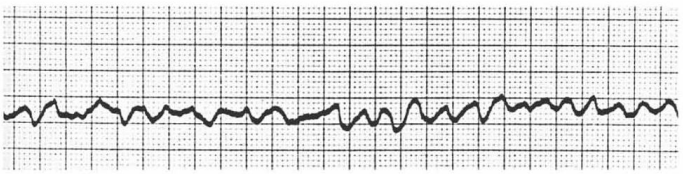
Sinus bradycardia



Ventricular tachycardia



(a) Sinus tachycardia



(b) Ventricular fibrillation

Flutter and Fibrillation

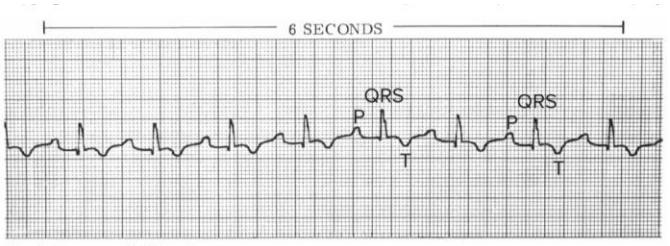
- _____: extremely fast (200 to 300 bpm) but coordinated contractions
- Fibrillation: uncoordinated pumping between the atria and ventricles

Types of Fibrillation

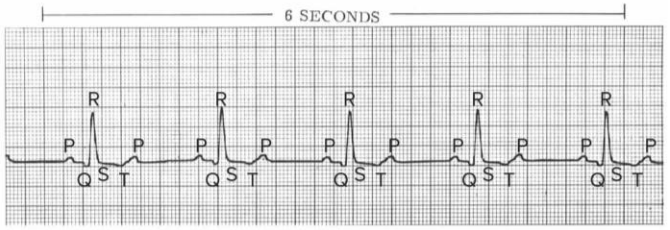
- _____ fibrillation:
  - Can result from atrial flutter
  - Atrial muscles cannot effectively contract.
  - AV node can't keep pace with speed of atrial contractions, but some stimulation is passed on.
  - Only reduces cardiac output by 15%
  - Associated with increased risk of thrombi, stroke, and heart failure
- _____ fibrillation

- Ventricles can't pump blood, and victim dies without CPR and/or electrical defibrillation to reset the heart rhythm.
- Caused by circus rhythms – continuous cycling of electrical waves
- Refractory period prevented
- Sudden death progresses from ventricular tachycardia, through ventricular fibrillation, ending in asystole (straight-line ECG)

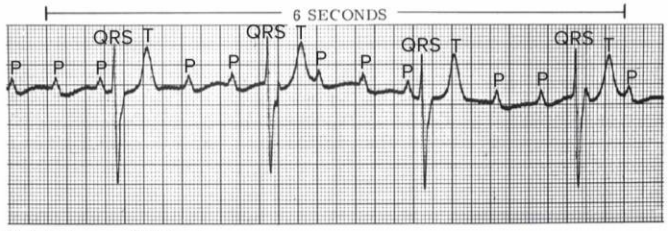
- _____ Node Block
  - Damage to the AV node can be seen in changes in the P-R interval of an ECG.
  - First degree: Impulse conduction exceeds 0.2 secs.
  - Second degree: Not every electrical wave can pass to ventricles
  - Third degree/complete: No stimulation gets through. A pacemaker in the Purkinje fibers takes over, but this is slow (20 to 40 bpm).



First-degree AV block



Second-degree AV block



Third-degree AV block

Topic 21: Study Guide Questions (preppages)

1. The interconnected structures that allow cardiac muscle cells to pass electrical impulses rapidly from cell to cell are called:
   A. Sarcomeres
   B. Intercalated discs
   C. Myofibrils
   D. Desmosomes
2. The region of cardiac tissue that contracts together in response to a single stimulation event is known as the:
   A. Myocardium or functional syncytium
   B. Conducting bundle
   C. Vasculature system
   D. Telodendrion
3. The heart's natural pacemaker is located in the:
   A. Left ventricle
   B. Right atrium
   C. Left atrium
   D. AV bundle
4. Pacemaker potential occurs due to the spontaneous opening of which type of channels?
   A. Voltage-gated K+ channels
   B. HCN channels
   C. Sodium-potassium ATPase pumps
   D. SERCA pumps
5. At approximately −40 mV, pacemaker cells trigger an action potential by opening:
   A. Fast Na+ channels
   B. Voltage-gated Ca2+ channels
   C. Cl− leak channels
   D. NCX exchangers
6. Parasympathetic neurons slow the heart rate primarily by increasing permeability to:
   A. Na+
   B. Ca2+
   C. K+
   D. Cl−
7. The plateau phase of a myocardial action potential is caused by a balance between:
   A. Na+ influx and Cl− efflux
   B. Ca2+ influx and K+ efflux
   C. Ca2+ efflux and Na+ influx
   D. K+ influx and Na+ efflux
8. Which part of the conduction system slows impulse conduction, creating a delay between atrial and ventricular contraction?
   A. SA node
   B. AV node
   C. Purkinje fibers
   D. Bundle of His
9. The S-T segment of an ECG corresponds to which event?
   A. Atrial repolarization
   B. Ventricular depolarization
   C. Plateau phase of ventricular systole
   D. Opening of semilunar valves
10. The "lub" heart sound occurs immediately after which ECG feature?
    A. P wave
    B. QRS complex
    C. T wave
    D. P-R interval

11. Beta-blocker drugs used for arrhythmias are categorized as which class of antiarrhythmic drugs?
A. Group 1
B. Group 2
C. Group 3
D. Group 4

12. Elastic arteries are characterized by their ability to:
A. Provide most peripheral resistance
B. Recoil during ventricular relaxation
C. Contain fenestrations
D. Permit exchange of gases

13. Which statement best describes arterioles?
A. They store most of the body's blood
B. They permit protein passage
C. They provide the greatest resistance to blood flow
D. They contain venous valves

14. Discontinuous capillaries are typically found in the:
A. Kidneys
B. Intestines
C. Central nervous system
D. Liver and spleen

15. Veins return blood to the heart with the help of all the following EXCEPT:
A. Skeletal muscle pumps
B. Venous valves
C. High arterial pressure
D. Breathing movements

16. Which condition is associated with plaque buildup due to endothelial damage and inflammation?
A. Deep vein thrombosis
B. Atherosclerosis
C. Varicose veins
D. Hemorrhagic stroke

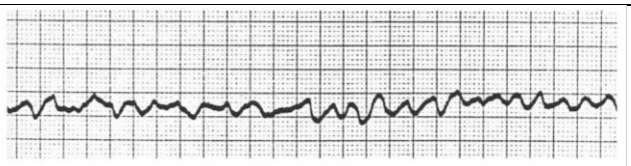
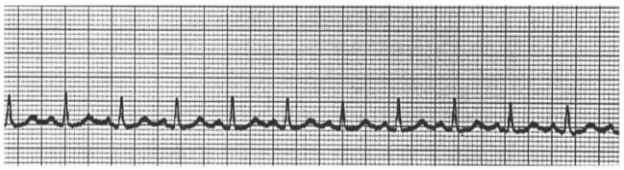
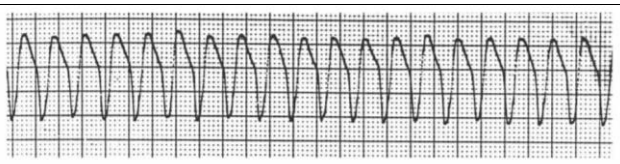
17. Which lipoprotein delivers cholesterol to arterial walls and promotes plaque formation?
A. HDL
B. LDL
C. VLDL
D. Chylomicrons

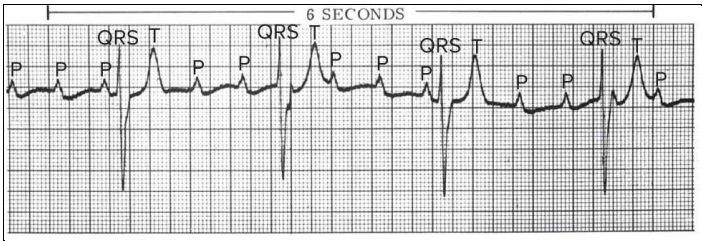
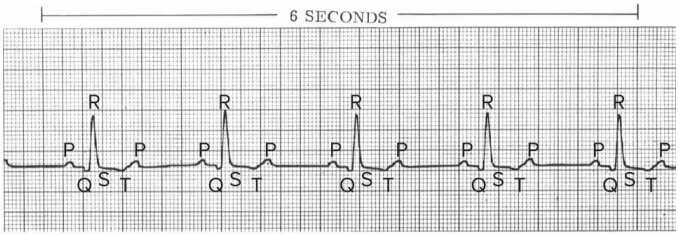
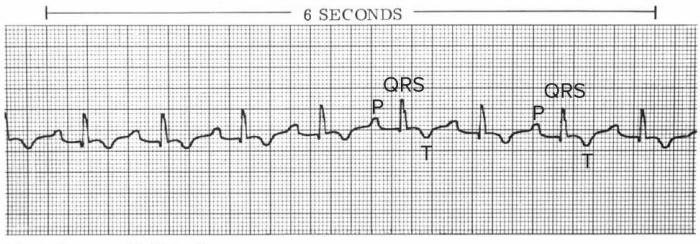
18. Ischemic heart disease is most commonly caused by reduced blood flow from:
A. Faulty venous valves
B. Coronary artery atherosclerosis
C. Dilated lymph vessels
D. Increased blood viscosity

19. Atrial fibrillation reduces cardiac output because:
A. Ventricles contract too slowly
B. Atria cannot pump effectively
C. SA node fires erratically
D. Purkinje fibers take over as pacemaker

20. A third-degree AV block is characterized by:
A. Slightly prolonged P-R interval
B. Some impulses not reaching ventricles
C. No conduction from atria to ventricles
D. Irregular SA node firing

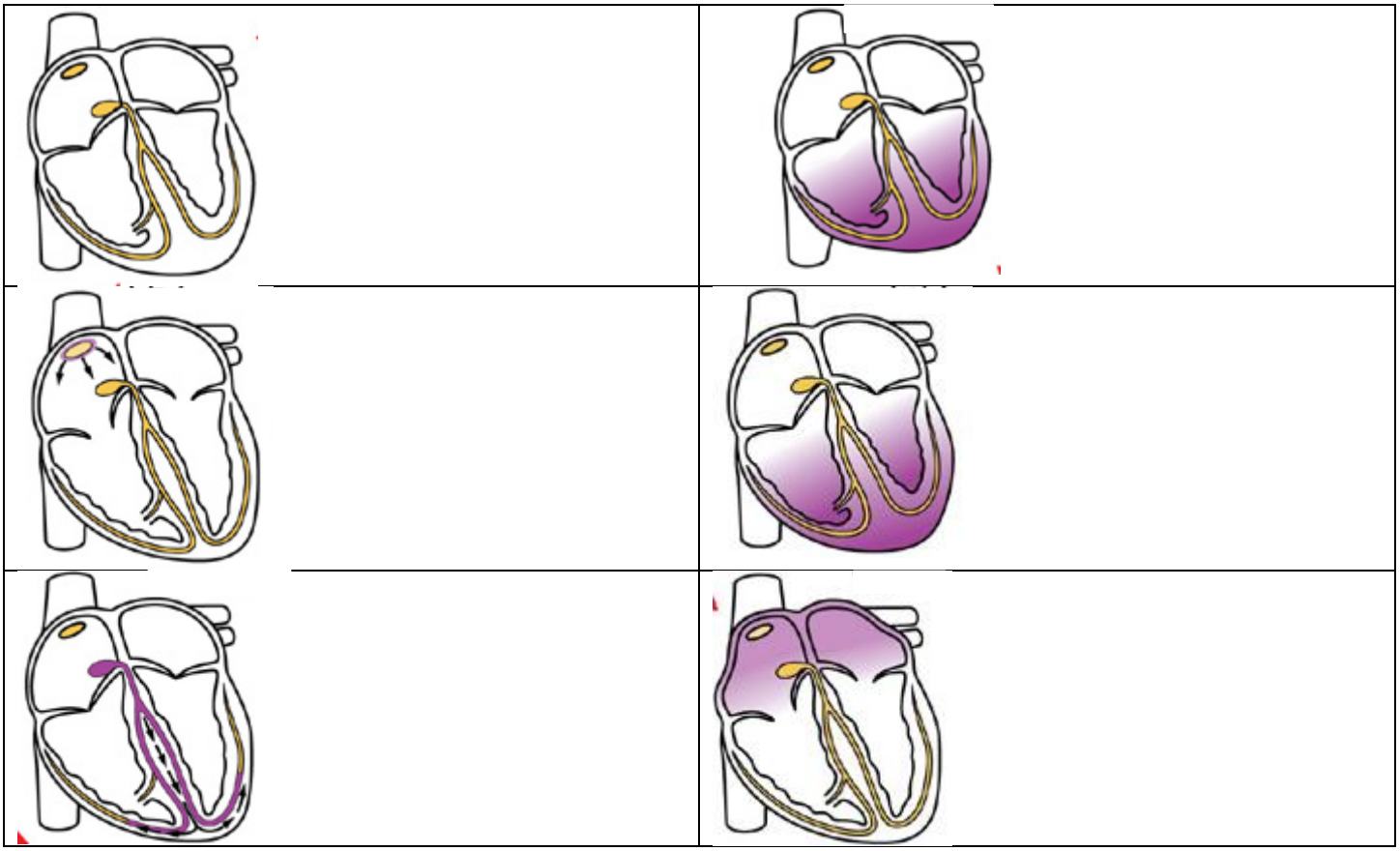
Identify the following EKG traces below: Using: 1st degree AV block, 2nd degree AV block, 3rd degree AV block, ventricular tachycardia, sinus bradycardia, sinus tachycardia, ventricular fibrillation

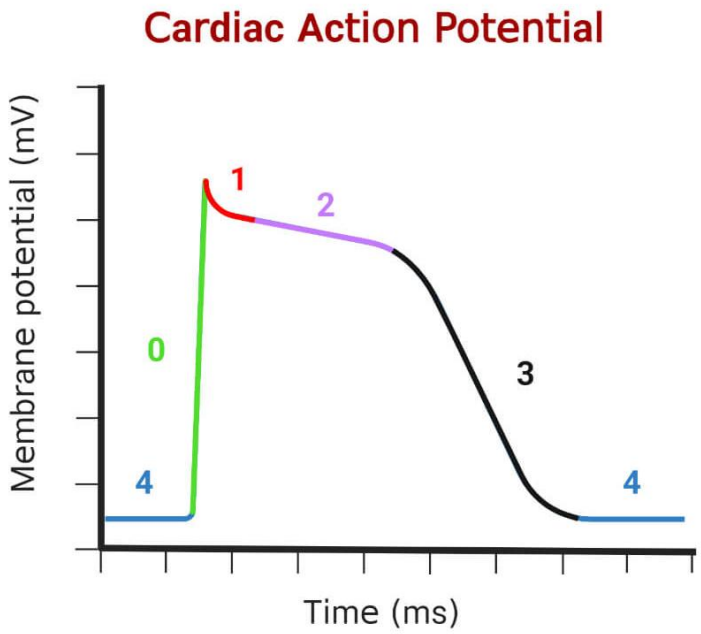
	
	
	

Fill in the missing labels of the EKG wave:
Identify the p-wave, QRST complex, T-wave, PR interval, ST segment, R-R interval

Identify how the action potentials spread in the heart: Label next to which images would be first, second, third, fourth, fifth, and sixth based on how action potentials spread in the heart. Indicate what image would represent/be associated with the p-wave portion, the QRS complex, and the t-wave. Which images represent atrial depolarization vs. ventricular repolarization.



Identify the parts of the graph that represent influx/efflux of the cardiomyocyte: Na+ in, K+ out, Ca2+ in and K+ out, K+ and Cl- out, RMP



Helpful images: