1	
2	Types of Cardiac Cells
	Myocardial cells Working or mechanical cells Contain contractile filaments Pacemaker cells Specialized cells of the electrical conduction system
	 Responsible for the spontaneous generation and conduction of electrical impulses
3	Properties of Pacemaker Cells
	Automaticity
	 Ability of cardiac pacemaker cells to spontaneously initiate an electrical impulse without being stimulated from another source (such as a nerve) Excitability
	Ability of cardiac muscle cells to respond to an outside stimulus Conductivity
	 Ability of a cardiac cell to receive an electrical stimulus and conduct that impulse to an adjacent cardiac cell
4	Properties of Myocardial Cells
	Contractility
	 Ability of cardiac cells to shorten, causing cardiac muscle contraction in response to an electrical stimulus Extensibility the ability of the cell to stretch
5	Cardiac Action Potential
	All living cells maintain a difference in the concentrations of ions across their cell membranes
	Electrical impulses are the result of brief but rapid flow of ions (charged particles) back and forth across the cell membrane
6	Cardiac Action Potential
	The exchange of electrolytes in myocardial cells creates electrical activity Appears on the ECG as waveforms Major electrolytes that affect cardiac function: Sodium Potassium
	- Calcium
7	Cardiac Action Potential
	 Differences in ion concentrations across the cell (the ionic gradient) determine the cell's electrical charge There is normally a slight excess of: Positive ions outside the membrane Negative ions inside the membrane
	Results in a difference in electrical charge across the membrane called the "membrane potential"
8	Cardiac Action Potential
	"Threshold" is the membrane potential at which the cell membrane will depolarize and generate an action potential
	Action potential

- A five-phase cycle that reflects the difference in the concentration of these ions across the cell membrane at any given time

- Specific ions or other small, water-soluble molecules can cross the cell membrane from outside to inside

9 Membrane Channels

Cell membranes contain membrane channels (pores)

10	Cardiac Action Potential
	A series of events causes the electrical charge inside the cell to change from its resting state (negative) to its depolarized (stimulated) state (positive) and back to its resting state (negative)
	 The cardiac action potential is an illustration of these events in a single cardiac cell during polarization, depolarization, and repolarization
11	Types of Action Potentials
	Two types of action potentials in the heart Fast Slow
	Classification is based on rate of voltage change during depolarization of cardiac cells
12 🔲	Fast-Response Action Potentials
	Occur in cells of the atria, ventricles, and Purkinje fibers Have voltage-sensitive sodium channels
	Myocardial fibers with a fast-response action potential can conduct impulses at relatively rapid rates
13	Slow-Response Action Potentials
	Normally occur in the SA and AV nodes
	- Can occur abnormally anywhere in the heart, usually secondary to ischemia, injury, or an electrolyte imbalance
	Possess slow calcium and slow sodium channels
	Slower rate of conduction compared to cardiac cells with fast sodium channels
14	Polarization, Depolarization, and Repolarization
15	Polarization = Resting
	Polarization
	Also called the resting membrane potential Resting state during which no electrical activity occurs
4.	Inside of the cell is more negative than the outside
16	
17	Depolarization = Stimulation
	Inside of the cell becomes more positive due to inward diffusion of Na+
	On the ECG: P wave represents atrial depolarization QRS complex represents ventricular depolarization
18	
19	Depolarization
	Depolarization is <u>not</u> the same as contraction
	 Depolarization is an electrical event expected to result in contraction (a mechanical event)
	It is possible to view electrical activity on the cardiac monitor, yet evaluation of the patient reveals no palpable pulse
	 Pulseless electrical activity (PEA)

20 Repolarization = Resting

21 Phases of the Action Potential

Outward diffusion of K+
 — Membrane potential returns to its negative resting level
 On the ECG:
 — ST segment represents early ventricular repolarization
 — T wave presents ventricular repolarization

- Action potential of a cardiac cell consists of five phases
- Reflects rapid sequence of voltage changes across cell membrane during electrical cardiac cycle

22 Phase 0 – Depolarization

- Begins when the cell receives an impulse
 - Sodium moves rapidly into cell
 - Potassium leaves cell
 - Calcium moves slowly into cell
- · Cell depolarizes and cardiac contraction begins
- Responsible for QRS complex on the ECG

23

Phase 1 – Early Repolarization

- Phase 1 is an early, brief period of limited repolarization
 - Fast Na+ channels partially close
 - Transient outward movement of K+ through K+ channels
 - Results in a decrease in positive electrical charges within the cell



6 Phase 2 – Plateau Phase

- · Repolarization continues relatively slowly
 - Caused by slow inward movement of Ca++ and slow outward movement of K+ from the cell
- Responsible for ST segment on ECG

Phase 3

- Phase of late and rapid repolarization
 - K+ flows quickly out of the cell
 - Slow channels close, stopping influx of Ca++ and Na+
 - Cell becomes progressively more electrically negative and more sensitive to external stimuli
- Corresponds with T wave on the ECG



29 Phase 4

Phase 4 - Return to Resting State

- Phase 4 is the resting membrane potential (return to resting state)
 - Heart is "polarized" during this phase (ready for discharge)
- Cell will remain in this state until reactivated by another stimulus

Refractory Periods

- Refractoriness
- The extent to which a cell is able to respond to a stimulus
- Absolute refractory period
 - Onset of QRS complex to approximately peak of T wave
 - Cardiac cells cannot be stimulated to conduct an electrical impulse, no matter how strong the stimulus

Refractory Periods

- Relative refractory period
 - Corresponds with the downslope of the T wave
 - Cardiac cells can be stimulated to depolarize if the stimulus is strong enough

2

- Supernormal period
 - Corresponds with the end of the T wave

	A weaker than normal stimulus can cause depolarization of cardiac cells
32 🔲	The Conduction System
32	
	Conduction system
	 Specialized electrical (pacemaker) cells in the heart arranged in a system of pathways
	Normally, the pacemaker site with the fastest firing rate controls the heart
33	Sinoatrial (SA) Node
	Located at the junction of the superior vena cava and the right atrium
	Initiates electrical impulses at a rate of 60 to 100 beats/min
	Normally the primary pacemaker of the heart
34	Atria
	Fibers of SA node connect directly with fibers of atria
	Impulse leaves SA node and is spread from cell to cell across the atrial muscle
35	Internodal Pathways
	Conduction through the AV node begins before striet depolarization is completed
	Conduction through the AV node begins before atrial depolarization is completed Impulse is spread to AV node via internodal pathways
	Pathways merge gradually with cells of AV node
36 🔲	AV Junction
	Area of specialized conduction tissue
	Provides electrical links between atrium and ventricle
37	AV Node
	Located in the posterior septal wall of the right atrium Supplied by right coronary artery in most individuals
	As the impulse from the atria enters the AV node, there is a delay in conduction of the impulse to the ventricles
	 Allows time for atria to empty contents into ventricles
38 🔲	AV Node
	Divided into three functional regions according to their action potentials and responses to electrical and chemical stimulation.
	Atrionodal (AN) or upper junctional region
	- Nodal (N) region
00	- Nodal-His (NH) AV Node
39	The primary delay in the passage of the electrical impulse from the atria to the ventricles occurs in the AN and N areas of the AV node
40	Bundle of His
	Also polled the "corresponder" or the "AV hundle"
	Also called the "common bundle" or the "AV bundle"
	Normally the only electrical connection between the atria and the ventricles
	Connects AV node with bundle branches
	 Has pacemaker cells capable of discharging at an intrinsic rate of 40 to 60 beats/min
	Conducts impulse to right and left bundle branches
41	Right & Left Bundle Branches
	Right bundle branch

- Innervates the right ventricle
- · Left bundle branch
 - Spreads the electrical impulse to the interventricular septum and left ventricle
 - Divides into three divisions (fascicles)
 - Anterior fascicle
 - Posterior fascicle
 - Septal fascicle

42 Purkinje Fibers

- Elaborate web of fibers that penetrate about 1/3 of the way into the ventricular muscle mass
 - Become continuous with cardiac muscle fibers
- Receive impulse from bundle branches and relay it to ventricular myocardium
- Intrinsic pacemaker ability of 20 to 40 beats/min

43 Causes of Dysrhythmias

44 Enhanced Automaticity

- · An abnormal condition in which:
 - Cardiac cells not normally associated with the property of automaticity begin to depolarize spontaneously or
 - Escape pacemaker sites increase their firing rate beyond that considered normal

45 Reentry

Propagation of an impulse through tissue already activated by that same impulse

46 Escape Beats or Rhythms

- Escape: term used when the SA node slows down or fails to initiate depolarization and a lower site spontaneously produces electrical
 impulses, assuming responsibility for pacing the heart
- "Protective" mechanisms
 - Maintain cardiac output
 - Originate in the AV junction or the ventricles

47 Heart Rate

- Autonomic nervous system (ANS) influences:
 - Heart rate
 - Conductivity
- Contractility

48 Baroreceptors

- Also called "pressoreceptors"
 - Specialized nerve tissue
 - Found in internal carotid arteries / aortic arch
 - Detect changes in blood pressure

49 Chemoreceptors

- · Located in internal carotid arteries and aortic arch
- Detect and respond to changes in:
 - Oxygen content of the blood
 - pH
 - Carbon dioxide tension

50 Parasympathetic Stimulation

- Major parasympathetic nerves are the two vagus nerves
 - One on each side of the body
- Vagus nerve innervates heart at SA and AV nodes
- Primary postganglionic neurotransmitter = acetylcholine

51 Parasympathetic Stimulation

- · Effects of acetylcholine
 - Slowing of rate of discharge of SA node
 - Slowing of rate of conduction through AV node

Sympathetic Stimulation

- Impulses sent from accelerator center in medulla travel along sympathetic fibers
- Primary postganglionic neurotransmitter = norepinephrine

Receptor Sites

- Alpha
 - Vascular smooth muscle
 - Beta-1 • Beta-2
 - Heart
- Bronchial smooth muscle
- Skeletal blood vessels
- Dopaminergic
 - Coronary arteries, renal, mesenteric, and visceral blood vessels

Effects of Norepinephrine on Receptor Sites

- Alpha
- No effect on heartPeripheral vasoconstriction
- Beta-1
 - Increased heart rate
 - Increased conductivity
 - Increased contractility

55 🔲 **Chronotropic Effect**

- Refers to a change in heart rate
 - A positive chronotropic effect refers to an increase in heart rate
 - A negative chronotropic effect refers to a decrease in heart rate

56 Inotropic Effect

- Refers to a change in myocardial contractility
 - A positive inotropic effect results in an increase in myocardial contractility
 - A negative inotropic effect results in a decrease in myocardial contractility