Continuing Education Material:

Basic Electrocardiography

ABP, LLC

BASIC ELECTROCARDIOGRAPHY

OBJECTIVES

1. Describe the anatomy and physiology of the heart and circulatory system.
2, Discuss basic electrophysiology of the heart.

3. Lean to identify the basic waveforms on the electrocardiogram.

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This continuing education material, Basic Electrocardiography, will earn the student 1.5 contact hours. If you have any questions regarding this information or would like further information on other continuing education opportunities, please contact:

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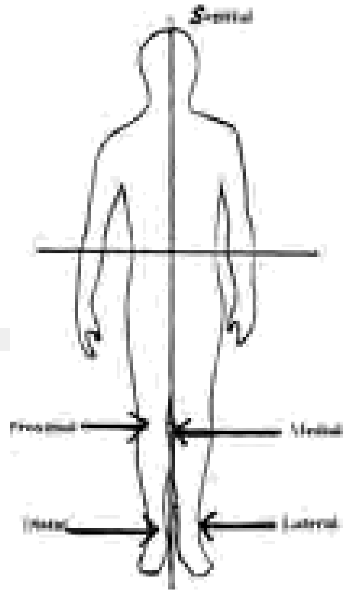
INTRODUCTION



ANATOMY: The branch of science that deals with the <u>structure</u> of living things

PHYSIOLOGY: The branch of science that deals with the <u>function</u> of living things

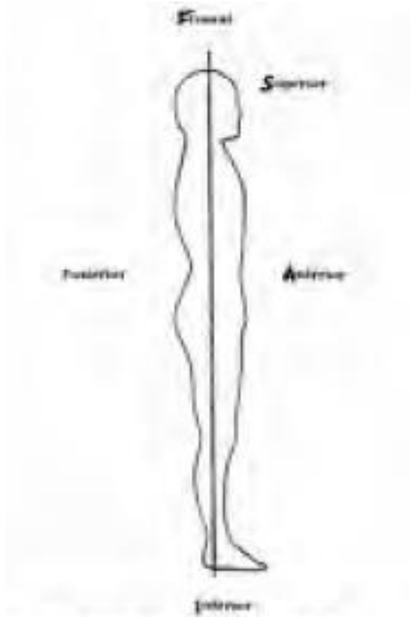
BODY PLANES

SAGITTAL: This place runs lengthwise (vertically) and divides the body into right and left halves

FRONTAL: This plane runs lengthwise (vertically) and divides the body into front and back halves.

TRANSVERSE: This plane runs lengthwise (horizontally) and divides the body into upper and lower halves.

BODY DIRECTIONAL SYSTEMS



The body's directional systems are used to describe the location of different anatomical structures and occur in pairs that are opposite each other.

Superior (cranial):	above or toward the head
Inferior (caudal):	below or away from the head
Anterior (ventral):	front side
Posterior (dorsal):	back side
Medial:	toward the midline
Lateral:	toward the side
Proximal:	nearest to the point of attachment or center of body
Distal:	farthest away from the pint of attachment or center of body

CIRCULATORY SYSTEM

The circulatory system is the link between all the body systems and it has three main components: blood, the heart and the blood vessels.

Blood is composed of water, solutes (proteins, nutrients, etc) and cellular elements. The functions of blood include: transportation of oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs; distribution of nutrients; transportation of waste products; delivery of enzymes and hormones; pH and electrolyte regulation; coagulation; body defense; and regulation of body temperature.

There are three kinds of blood vessels in the body: arteries, veins and capillaries.

Arteries carry oxygenated blood (except for the pulmonary artery) <u>away</u> from the heart and branch into smaller vessels called arterioles. They have thick, elastic walls that expand with the surge of blood. The arteries have no valves but do have a pulse. The aorta is the largest artery in the body.

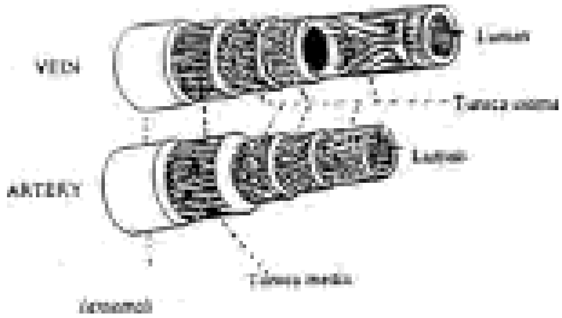
Veins carry deoxygenated blood (except for the pulmonary vein) <u>to</u> the heart and branch into smaller vessels called venules. They have thin, less elastic walls and contain valves to prevent a back flow of blood from occurring. Veins do not pulsate. The largest veins in the body are the superior and inferior vena cava.

Veins and arteries have three layers:

1. **Tunica adventitia (externa):** outer layer made up of connective tissue; thicker in arteries than in veins
2. **Tunica media:** middle layer made up of smooth muscle tissue; thicker in arteries than veins
3. **Tunica intima:** inner layer or lining made up of a single layer of endothelial cells

Capillaries are the smallest vessels in the body. They are composed of a single layer of endothelial cells and link the venules (small veins) to the arterioles (small arteries). Capillaries are responsible for the exchange of gases between the cells and the blood, i.e. the oxygen in the blood is exchanged for the carbon dioxide in the cells.

COMPARATIVE STRUCTURES OF A VEIN AND ARTERY



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THE HEART

The **heart** is the simples, but most vital body organ. The heart secrets no hormones, breaks down no enzymes, detects no external stimuli and neither adds nor deletes substances in the blood. The heart does not exist independent of other body organs. The medulla of the brain innervates the heart where sight, sound, touch and physical activity are monitored and directs the body’s physical requirements.

The heart is located in the thoracic cavity behind the sternum and between the lungs. It is surrounded by a protective sac called the **pericardium**. The pericardium sac is fluid filled and covers the heart’s entire outer surface as well as protects the heart’s chambers from friction. The heart is a hollow, organ with four chambers.

The muscular wall of the heart consists of three layers:

1. **Epicardium** or thin outer layer
2. **Myocardium** or think middle layer
3. **Endocardium** or thin inner layer which lines the chambers of the heart and covers the heart valves

The heart is about the size of man’s fist and functions as a double pump. The two upper chambers of the heart are called **atria** and the two lower chambers are called **ventricles.** The chambers are divided by a muscular wall called the septum and forms two “pumps,” the pulmonary and the systemic, each consisting of one atrium and a corresponding ventricle. Contractions of the myocardium force blood in and out of the chambers. Valves regulate the direction of blood flow and prevent a backflow.

THE VALVES OF THE HEART

The **tricuspid** and **mitral** valves are called **atrioventricular (AV)** valves because they separate the atria from the ventricles (the tricuspid on the right, mitral on the left). These valves are prevented from bulging back into the atria during ventricular systole, or contraction, by

VALVE	NAME	LOCATION
Atrioventricular (AV)	Tricuspid	Separates right atrium and right ventricle
	Mitral (Bicuspid)	Separates left atrium and left ventricle
Semilunar	Pulmonic	Between right ventricle and pulmonary artery
	Aortic	Between left ventricle and aorta

During relaxation and filling of the atria and ventricles (diastole), about 2/3 of the atrial blood flows passively from the atria into the ventricles. When atrial contraction occur, atrial blood is pushed into the ventricles. This atrial contribution is called **atrial kick** and accounts for 10-30% of the cardiac output (the amount of blood ejected by the left ventricle into the aorta in one minute).

Diastole: ventricular relaxation phase, chambers fill with blood
Systole: ventricular contraction phase

The first heart sound (S1) is the result of closure of the tricuspid and mitral (AV) valves during ventricular contraction. The second heart sound (S2) occurs at the end of ventricular contraction because of the closure of the aortic and pulmonic (semilunar) valves.

HEART AND BLOOD FLOW

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1. Superior Vena Cava
2. Inferior Vena Cava
3. Right Atrium
4. Tricuspid Valve
5. Pulmonary Valve
6. Right Ventricle
7. Septum
8. Left Ventricle
9. Mitral (Bicuspid) Valve
10. Aortic Valve
11. Left Atrium
12. Pulmonary Artery
13. Pulmonary Vein
14. Aorta

BLOOD FLOW CHART

Superior/Inferior Vena Cava
|
Right Atrium
|
Tricuspid Valve
|
Right Ventricle
|
Pulmonary Valve
|
Pulmonary Artery to Lungs
|
Pulmonary Vein from Lungs
|
Left Atrium
|
Bicuspid (Mitral) Valve
|
Left Ventricle
|
Aortic Valve
|
Aorta
|
Arteries
|
Arterioles
|
Capillaries
|
Venules
|
Veins
|
Back to the Vena Cava

FLOW OF BLOOD THROUGH THE HEART

Deoxygenated blood enters the right atrium through the superior and inferior vena cava, when the right atrium contracts, the blood goes through the tricuspid valve and enters the right ventricle. The right ventricle contracts and forces the blood through the pulmonary valve and into the pulmonary artery which carries the blood to the lungs where carbon dioxide is exchanged for oxygen. The pulmonary artery is the only artery which carries deoxygenated blood.

The **pulmonary circuit** of blood involves the blood from the right side of the heart and the lungs. The oxygenated blood comes back to the heart by way of the pulmonary vein. The pulmonary vein is the only vein which carries oxygenated blood. Blood goes from the pulmonary vein into the left atrium. When the left atrium contracts, the blood goes through the bicuspid or mitral valve into the left ventricle. As the left ventricle contracts, the blood is sent through the aortic valve and into the aorta. The left ventricle has the thickest wall and is the most muscular chamber of the heart since it is responsible for pumping the blood into the aorta and ultimately the rest of the body.

The **systemic circuit** of blood involves the oxygenated blood from the left side of the heart that leaves the left ventricle, goes through the aorta, travels to all the body systems and then back to the heart via the superior and inferior vena cava.

The heart also functions as a pressure chamber. The blood is at its lowest pressure, about 3 mm (millimeters) of mercury, when it enters the right atrium. The pressure increases to 20-30 mm Hg as the blood is pumped from the right ventricle into the lungs. The oxygenated blood which is forced into the aorta is at a pressure of 100-140 mm Hg in a normal adult. The peak pressure is called **systolic** pressure. The blood loses pressure as it travels through the body and then returns to the heart at 3 mm Hg. The lowest pressure is called the **diastolic** pressure.

The first heart sound heard is the result of the closure of the tricuspid and mitral valves during ventricular contraction (systole). The second heart sound is at the **end** of ventricular contraction or the relaxation phase and is the result of the closing of the pulmonary and aortic valves (diastole).

BLOOD SUPPLY TO THE CONDUCTION SYSTEM

The right and left coronary arteries supply blood to the myocardium during the relaxation phase. The right coronary artery divides into the posterior descending branch and the AV nodal branch. It supplies blood to the right atrium, the interior wall of the right ventricle, ½ the anterior surface of the left ventricle, the AV node (90% of patients), the SA node (55% of patients), and the bundle of His. The left coronary artery divides into the left anterior descending branch and the left circumflex branch. The left anterior descending branch supplies blood to the anterior surface of the left ventricle, all bundle branches and part of the right ventricle. The left circumflex branch supplies blood to the left atrium, the lateral wall of the left ventricle and the SA note (45% of patients). **The most important factor that determines the amount of blood pumped by the heart is the amount of blood received from the systemic circulation.**

THE AUTONOMIC NERVOUS SYSTEM AND CONTROL OF THE HEART

The **autonomic** nervous system controls the visceral functions of the heart, distributing impulses to the heart, smooth muscle and glands. It consists of cardiac nerves that control the conduction system and contractibility of the heart.

The heart is innervated by two divisions of the autonomic system; the **sympathetic** and the **parasympathetic**. The medulla in the brain contains two cardiac centers: the **accelerator** center and the **inhibitory** center.

Sympathetic nerve fibers from the accelerator center innervate both the atria and ventricles, but effect primarily the ventricles. Stimulation of the sympathetic nerve fibers results in the release of norepinephrine, which increases the force of ventricular contraction, heart rate, blood pressure and cardiac output.

Parasympathetic nerve fibers from the inhibitory center innervate the SA and AV nodes of the heart by means of the vagus nerve. Stimulation of the paracympathetic nerve fibers causes the release of aceylcholine, which results in a slowing of the rate of discharge of the sinus node and slowing the rate of conduction through the AV node, resulting in slowing of the heart rate. Thus, the effect of the parasympathetic system in supraventricular.

BASIC ELECTROPHYSIOLOGY

Cardiac cells are specialized to perform three function. The **pacemaker cells** generate electrical impulses; **conducting cells** conduct impulses through the myocardium; and **myocardial cells** contract with response to the impulses. Cardiac cells have both electrical and mechanical properties. Electrical properties are responsible for impulse formation and the distribution of the impulses in an orderly fashion along the conduction pathway of the heart. **Electrical properties include: automaticity, excitability, conductivity** and **refractoriness.**

Automaticity is the ability of a cardiac cell to spontaneously initiate an electrical impulse without being stimulated from another source. The SA node, AV node and Purkinje fibers possess this characteristic. When a cardiac cell becomes somewhat permeable to sodium (Na^+) and calcium (Ca^{++}) ions and somewhat impermeable to potassium (K^+) ions diffuse out of the cell and Na^+ ions are pumped out, leaving the interior with a strong negative charge.

Excitability (irritability) is the ability of a cardiac cell to respond to an outside stimulus. During the resting state of a cardiac cell, there is a buildup of positive ions outside the cell. K^+ ions diffuse out of the cell and Na^+ ions are pumped out, leaving the interior with a strong negative charge.

Conductivity is the ability of a cardiac cell to receive an electrical stimulus and conduct or transmit that impulse from one cell to another cell. The cell's negative potential is discharged when the Na^+ channels open, permitting a flood of Na^+ ions into the cell interior. This discharge stimulates connecting cells and a current is conducted.

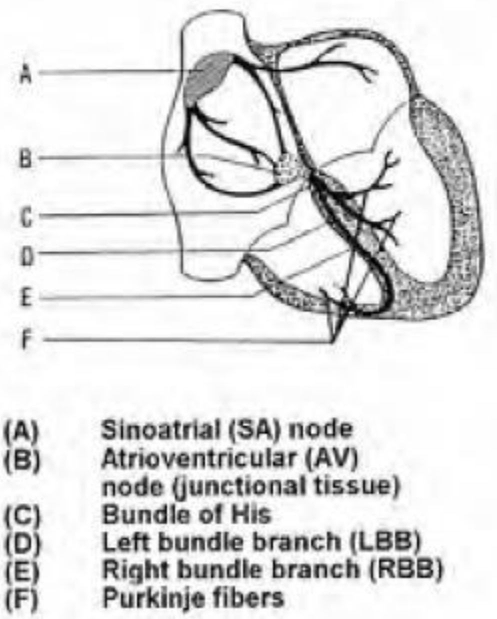
Refractoriness refers to the state of responsiveness of a cardiac cell. The cell is refractory (unable to respond) to another discharge until the Na^+ channels open. Meanwhile, the internal negative charge builds up as positive ions diffuse out or are pumped out, restoring the cell to its excitable resting state.

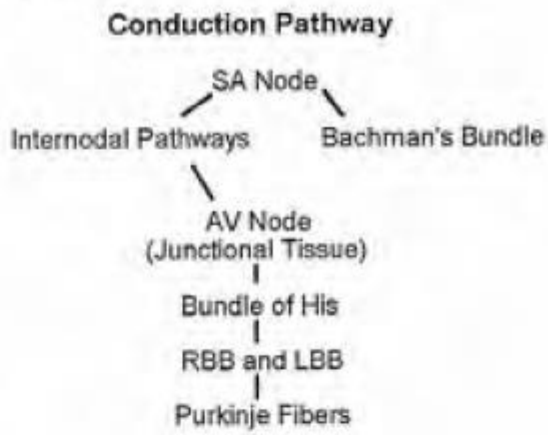
Mechanical properties are responsible for myocardial or muscular contractions.

Contractility is the ability of cardiac cells to shorten, causing cardiac muscle contraction in response to an electrical stimulus.

Extensibility is the ability of cardiac cells to stretch and relax after a contraction.

THE CONDUCTION SYSTEM





The pacemaker (specialized electrical) cells of the heart are arranged in a system of electrical pathways called the conduction system. The specialized cells or fibers are collected together in structures called nodes and bundles (located beneath the lining of the heart chambers) that form a network of pathways for the spread of electrical activity that sets off heart muscle contraction.

SINOATRIAL (SA) NODE

The SA node is a cluster of cells located in the upper wall of the right atrium close to the inflow tract of the superior and inferior vena cava. It is designated as the body's natural "pacemaker" because it is located highest in the heart and it has the fastest intrinsic (preset) firing rate of electrical impulses – 60 to 100 beats per minute (bpm).

INTERNODAL PATHWAYS and BACHMAN'S BUNDLE

The electrical impulses travel along three internodal pathways in the right atrium and along the Bachman's bundle to the left atrium to atrial muscle fibers and to the AV node.

ATRIOVENTRICULAR (AV) NODE

The AV node is a cluster of cells located at the lowest portion of the right atrium and above the base of the tricuspid valve. The AV node does not possess pacemaker cells but the junctional tissue around it does. The AV node, known as the "gatekeeper," has the special function of slowing down the impulse conduction rate.

In a normal heart, the AV node is the only pathway for conduction of atrial electrical impulses to the ventricles. The brief (.04 second) delay allows the atria to contract and the ventricles to fill with blood. The AV node monitors the heart rate and if it drops below 50 bpm, the junctional tissue surrounding the AV node takes over pacing with an intrinsic rate of 40-60 bpm.

BUNDLE OF HIS

The bundle of His, or common bundle, lies at the top of the interventricular septum and connects to the AV node with the right and left bundle branches. Its function is to conduct electrical impulses rapidly from the AV node to the ventricles. The region where the AV node joins the bundle of His is called the **AV junction** and has an intrinsic pacing rate of 40-60 bpm.

RIGHT AND LEFT BUNDLE BRANCHES

The right bundle branch (RBB) is long and thin. It lies beneath the endocardium on the right side of the interventricular septum and carries the electrical impulses to the right ventricle. The left bundle branch (LBB) is shorter and divides into two pathways that spread down the left side of the interventricular septum and throughout the left ventricle.

PURKINJE FIBERS

The Purkinje fibers are a diffuse muscle fiber network that lie beneath the endocardium. The RBB and LBB divide into smaller and smaller branches that eventually connect with the Purkinje fibers. The electrical impulses are conducted faster here than in any other region of the heart with the end result of ventricular contraction. The intrinsic pacing rate of the Purkinje fibers is 20-40 bpm.

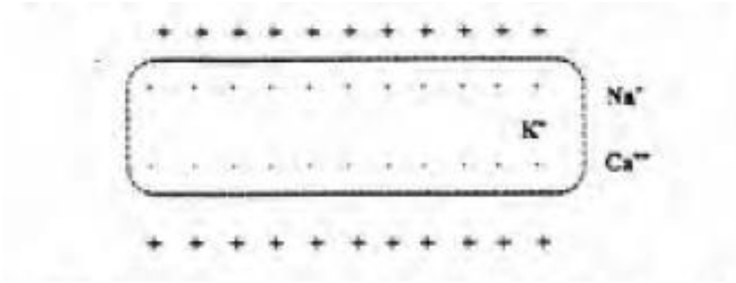
The bundle of His, RBB, LBB and Purkinje fibers work together to stimulate ventricular contraction and are known as the **His-Purkinje System**.

POLARIZATION, DEPOLARIZATION, REPOLARIZATION

These terms explain the connection between the electrical activity and the mechanical events that occur within the heart . In order for electrical current to tbe generated, there must be a difference between electrical charges. It is the exchange of the major electrolytes, i.e. Na^{+}, K^{+}, and Ca^{++}, in myocardial cells that creates electrical activity.

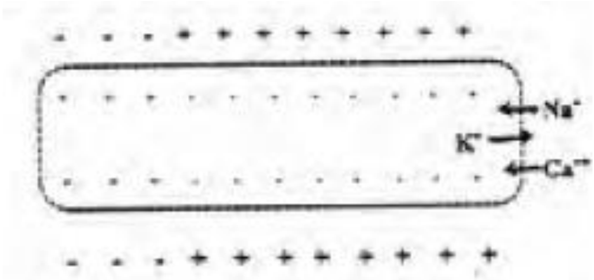
Each cardiac cell is surrounded by and filled with a solution that contains positive and negative ions.

POLARIZATION



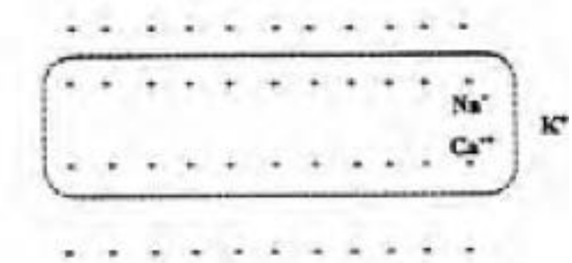
When the cardiac cell is polarized or resting, it is negatively charged on the inside and positively charged on the outside. When the heart is at rest, there is no impulse and thus no stimulation, no contraction and no measurable activity. The concentration of K_+ is higher inside the cell and Na_+ is higher outside the cell.

BEGINNING DEPOLARIZATION



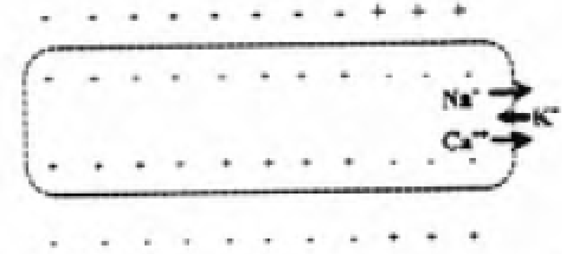
When the cardiac cell receives an electrical stimulus, the cell membrane allows Na_+ and Ca_{++} ions to enter the cell causing the K_+ ions to move outside the cell membrane. The inside of the cell begins to change from negative to positive.

COMPLETE DEPOLARIZATION



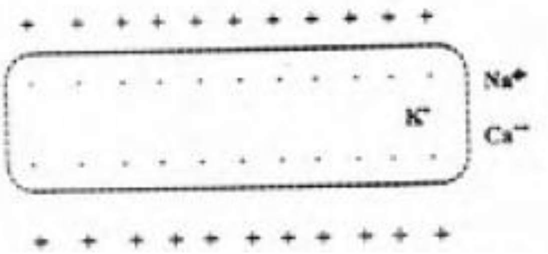
The advancing wave of positive ions generates an electrical current which causes a myocardial contraction. This currant changes the cell's internal electrical charge to positive as it depolarizes. This discharge of electrical energy can be measured by the electrocardiograph (ECG).

BEGINNING REPOLARIZATION



Following depolarization, the relaxation or recovers of the cardiac cell begins as the Na_+ and Ca_{++} ions pass out of the cell and K_+ ions move back into the cell.

COMPLETE REPOLARIZATION



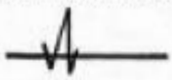
Recovery or repolarization is strictly an electrical event and , as such, can be measured by an ECG. The internal charge of the cardiac cell becomes negative again as the cell returns to a resting state.

ELECTRICAL CIRCUITRY AND THE ECG

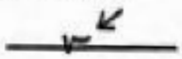
- Depolarization of the right and left atria are seen on the ECG as the **P wave**.

- There is a brief .04 second delay at the AV junction as the ventricles fill with blood and is seen on the ECG as the **PR segment**.

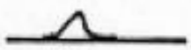
- Depolarization of the ventricles is seen as the **QRS complex** on the ECG.



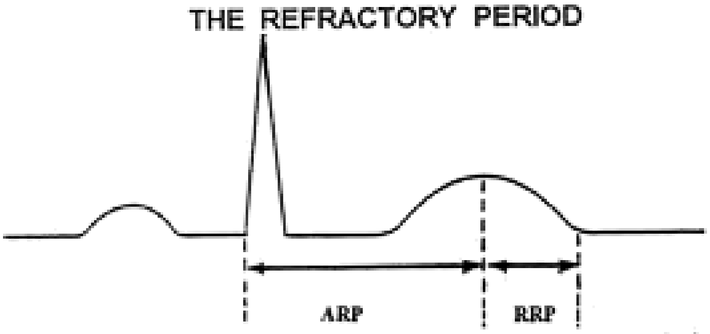
- After ventricular depolarization, there is a pause as the cardiac cells return to their resting state. This pause is represented on the ECG as the **ST segment**.



- Repolarization of the ventricles as the cells return to their resting state is represented on the ECG as the **T wave**.



THE REFRACTORY PERIOD



The refractory period of a cardiac cell corresponds with the onset of ventricular depolarization and the completion of ventricular repolarization and occurs in two phases.

The **absolute recovery period (ARP)**, also known as the **effective refractory period**, is the period of time during which the cardiac cells cannot respond nor conduct an electrical impulse, no matter how strong the stimulus. The ARP is represented on the ECG by the beginning of the QRS complex to the peak of the T wave.

The **relative refractory period (RRP),** also known as the **vulnerable period,** is the period in which some of the cardiac cells have repolarized enough that they can be stimulated to depolarize if the electrical stimulus is strong enough. The RRP is represented on the ECG by the down slope of the T wave.

CAUSES OF DYSRHYTHMIAS

Any disturbance in the normal rhythm of the cardiac cycle or the conduction pathway results in a dysrhythmia and present an abnormal electrical activity pattern. Enhanced automaticity, re-entry, escape beats and conduction disturbances can all result in dysrhythmias.

Enhanced automaticity occurs when cardiac cells not normally associated with the property of automaticity begin to depolarize spontaneously or when escape pacemaker sites increase their firing rate beyond the normal rate. It may occur as a result of medications, heart disease or electrolyte imbalance. Examples of rhythms associated with enhanced automaticity include atrial flutter and ventricular fibrillation.

Re-entry results when an impulse is delayed or blocked in one or more areas of the conduction pathway while the impulse is conducted normally through the rest of the conduction system. Thus, the impulse returns to stimulate tissue that was just stimulated or depolarized.

Some antidysrhythmic drugs, heart vessel blockage and hyperkalemia can cause re-entry. Examples of rhythms associated with re-entry include premature atrial complexes (PACs) and premature ventricular complexes (PVCs).

Escape beats occur when the SA node slows down or fails to initiate the electrical impulse and a lower pacemaker site assumes the responsibility for pacing the heart. Escape beats are protective measures to maintain cardiac output. They can be junctional or ventricular in origin.

Conduction disturbances which cause the electrical impulse to proceed too slowly or too fast can occur due to medications, electrolyte imbalances and heart disease. Heart blocks are examples of conduction disturbances.

THE ELECTROCARDIOGRAM

The electrocardiogram (ECG) records electrical impulses associated with cardiac contraction and relaxation. Atrial and ventricular depolarization and repolarization are electrical events seen as waves on the ECG monitor or on the ECG paper. The ECG records the **amount** of voltage generated by the heart and the **time** required for that voltage to travel through the heart.

The ECG complex is described by a series of letters that are recognized by the international medical community.

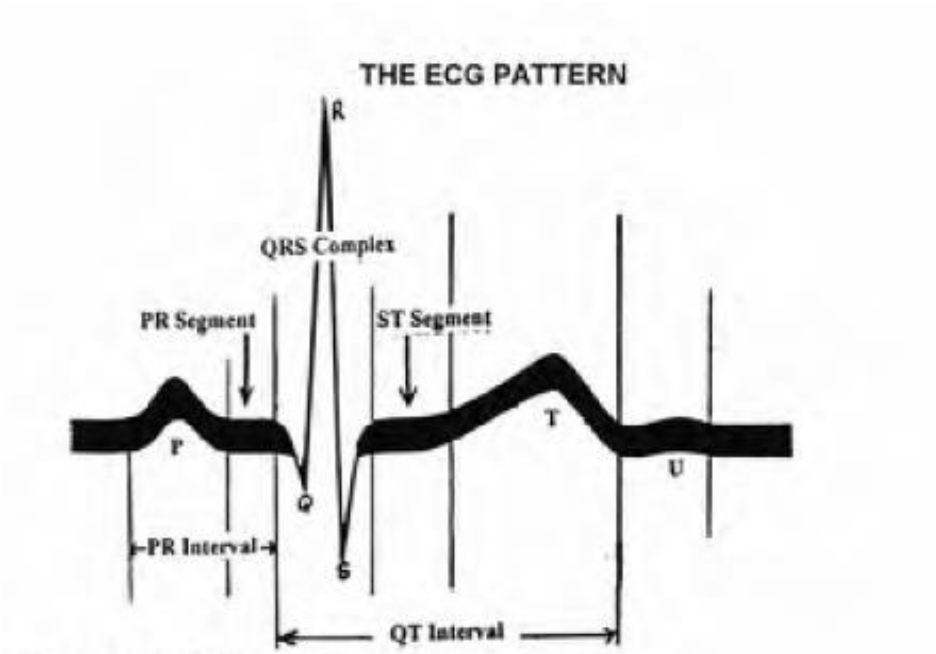
Baseline An isoelectric line or zero voltage line on the ECG. It represents the absence of electrical activity.

Waveform It represents the path of an electrical impulse as it travels through the heart. It can move away from the baseline in either a positive or negative direction. The five major waveforms are **P, Q, R, S, T.**

Segment A line between two waveforms which usually represents a pause in the electrical conduction of an impulse.

Interval It consists of a waveform plus a segment.

Complex A group of several waveforms recorded during a singular contraction.



P Wave

- First waveform seen in the cardiac cycle
- Represents depolarization of the right and left atria
- Normally small, smooth, slightly rounded
- Normal height 0.5-2.5 mm (millimeters), duration no more than 0.11 seconds
- Upright or positively deflected in leads I and II
- Most important factor in differentiating sinus rhythms from other ectopic rhythms

PR Segment

- Line between the P wave and the beginning of the QRS complex
- Represents the approximately 0.04 second delay at the AV node while the ventricles fill with blood
- Appears as a flat or isoelectric line

PR Interval

- The P wave plus the PR segment
- Time required for impulse to travel from the SA node through the atria to the AV node
- Time lapse between the onset of atrial contraction to the onset of ventricular contracton
- Normally measures 0.12 to 0.20 seconds

QRS Complex

- Consists of three waveforms: Q, R and S
- The Q wave is the first negative deflection prior to the R wave and may or may not be present; it represents depolarization of the interventricular septum.
- The R wave is the first positive (upright) deflection following the P wave. The amplitude differs in each of the 12 leads; positive in I, II, III, AVL, AVF, V, V, V, and negative in AVR, V, V, V.
- The S wave is the negative deflection following the R wave
- The R and S waves represent depolarization of the right and left ventricles
- The QRS complex represents the journey of the electrical impulse from the AV node rhgouth the Purkinje network.
- Duration of QRS complex is 0.10 second or less
- Atrial repolarization occurs during this time, but is not visible on the ECG

ST Segment

- Line between the QRS complex and the T wave
- Transition period between the end of ventricular contraction and the beginning of ventricular repolarization
- The point where the QRS complex and the ST segment meet is called the “junction” or “J” point.

- Duration is not usually measured

T Wave

- Represents ventricular repolarization; the peak of the T wave represents the beginning of the relative refractory period
- Amplitude 5 mm or less in leads I, II, and III; 10 mm or less in V, through V
- Usually rounded and smooth
- Deflection upright in I, II, III, AVF, V through V; may be inverted in AVR, AVL
- Duration not usually measured
- The T wave following an abnormal QRS complex is usually in the opposite direction of the QRS.

QT Interval

- Represents the amount of time between the beginning of ventricular contraction and the completion of ventricular recovers (repolarization)
- Includes the QRS complex, ST segment and T wave
- Duration 0.36 to 0.44 seconds but varies according to age, sex and heart rate
- The QT Interval should not be greater than one half the length of the R-R interval if the rhythm is regular

U Wave

- Represents repolarization of the Purkinje fibers
- Not easily identified because of low amplitude (less than 2 mm)
- Follows the T wave and usually in the same direction
- Rounded in shape and usually upright
- Appears as a result of a small, late electrical discharge from the heart

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ABP CONTINUING EDUCATION SELF-ASSESSMENT QUIZ

Basic Electrocardiography

Please answer all questions on the Continuing Education Registration Form:

1. All of the following are part of the muscular wall of the heart **except:**

   a. epicardium
   b. pericardium
   c. myocardium
   d. endocardium

2. Which of the following statements is correct?

   1. The tricuspid and bicuspid valves are semilunar valves.
   2. During diastole the pulmonic and aortic valves are closed.
   3. Systole is the contraction phase.
   4. The second heart sound heard is the closure of the tricuspid and bicuspid valve.

   a. 1 and 2 are correct
   b. 2 and 3 are correct
   c. 2 and 4 are correct
   d. 3 and 4 are correct

3. All of the blood that comes into the heart is brought in by veins carrying deoxygenated blood.

   a. True
   b. False

4. All of the following statements are correct **except:**

   a. Capillaries are the smallest blood vessels and where gas exchange actually occurs.
   b. When blood enters the right atrium it is at its highest pressure (100-140 mm Hg).
   c. Blood flow through the heart involves a pulmonary and systemic circuit.
   d. The thickest part of the heart wall is in the left ventricle.

5. Which of the following statements are correct?

   1. The inhibitory center of the heart is contained in the medulla and controlled by the parasympathetic nervous system.
   2. Norepinephrine is released by the parasympathetic nervous system.
   3. The left coronary artery divides into the left anterior descending branch and the left circumflex branch.
   4. The effect of the sympathetic system is primarily supraventricular.

   a. 1 and3 are correct
   b. 1, 2 and 3 are correct
   c. 2 and 3 are correct
   d. 2 and 4 are correct

6. Electrical properties of the heart include:

   a. automaticity, contractility, excitability, refractoriness
   b. automaticity, excitability, extensibility, refractoriness
   c. automaticity, extensibility, conductivity, refractoriness
   d. automaticity, excitability, conductivity, refractoriness

7. The major components of the conduction pathway include:

   a. SA node, AV node, His bundle, Purkinje fibers
   b. SA node, AV node, Bundle branches, Purkinje fibers
   c. SA node, AV node, His-Purkinje System
   d. SA node, intermodal pathways, His Bundle, Purkinje fibers

8. All the following statements about depolarization are correct **except**:

   a. the internal charge of the cardiac cell is positive
   b. atrial depolarization is represented by the P waveform
   c. ventricular depolarization is represented by the T waveform
   d. the concentration of extracellular K^+ is higher than intracellular K^+

9. Dysrhythmias can be caused by which of the following:

   a. refractoriness
   b. repolarization
   c. contractility
   d. enhanced automaticity

10. Which of the following statements about the QRS complex is correct?

    a. The duration of the complex is 0.12 to 0.20 seconds.
    b. It represents the time it takes the electrical impulse to travel from the AV node through the Purkinje network.
    c. It represents electrical recovery of the ventricles
    d. The waveforms are all positively deflected.