



UNIVERSITY OF
MEDICAL SCIENCES
ONDO STATE, NIGERIA

Cardiovascular Physiology

Adeyomoye O.I

Department of Physiology
University of Medical Sciences, Ondo



Course Outline

- ▶ **Introduction to cardiovascular system**
- ▶ **Functions of the cardiovascular system**
- ▶ **Cardiac muscle**
- ▶ **Cardio myoelectrophysiology**
- ▶ **Cardiac cycle**



Introduction to Cardiovascular system

- ▶ All living cells require metabolic substrates (e.g., oxygen, amino acids, glucose) and a mechanism by which they can remove by-products of metabolism (e.g., carbon dioxide, lactic acid).
- ▶ Single-cell organisms exchange these substances directly with their environment through diffusion and cellular transport systems.
- ▶ Most cells of large organisms have limited or no exchange capacity with their environment.
- ▶ Large organisms have a sophisticated system of blood vessels that transports metabolic substances between cells and blood, and between blood and environment.



The Cardiovascular System

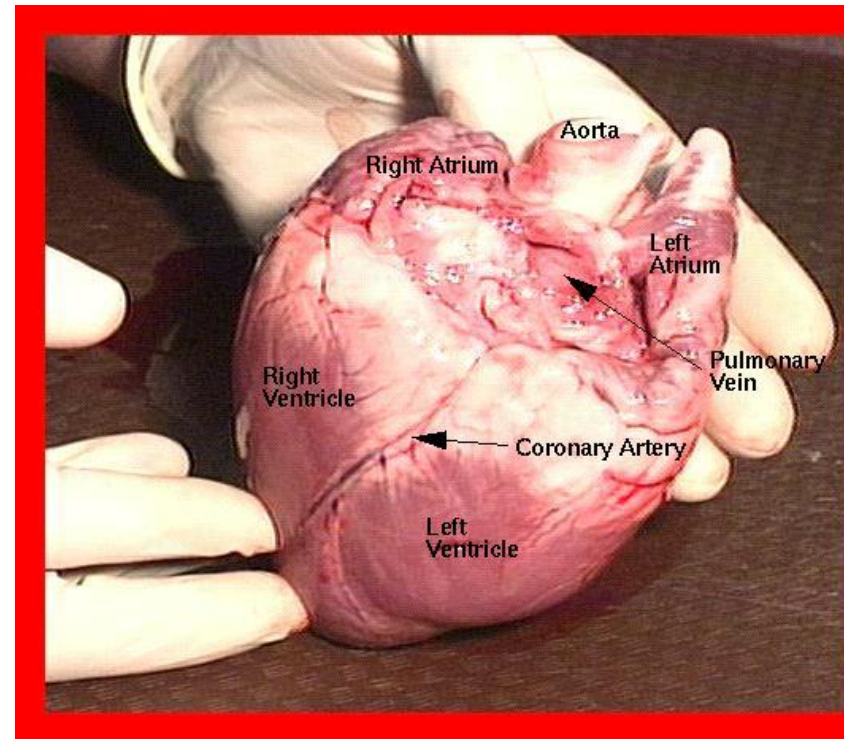
- ▶ The cardiovascular system has three primary elements: the heart, blood vessels and blood.
- ▶ A fourth component, the lymphatic system, does not contain blood, but nonetheless serves an important exchange function in conjunction with blood vessels.

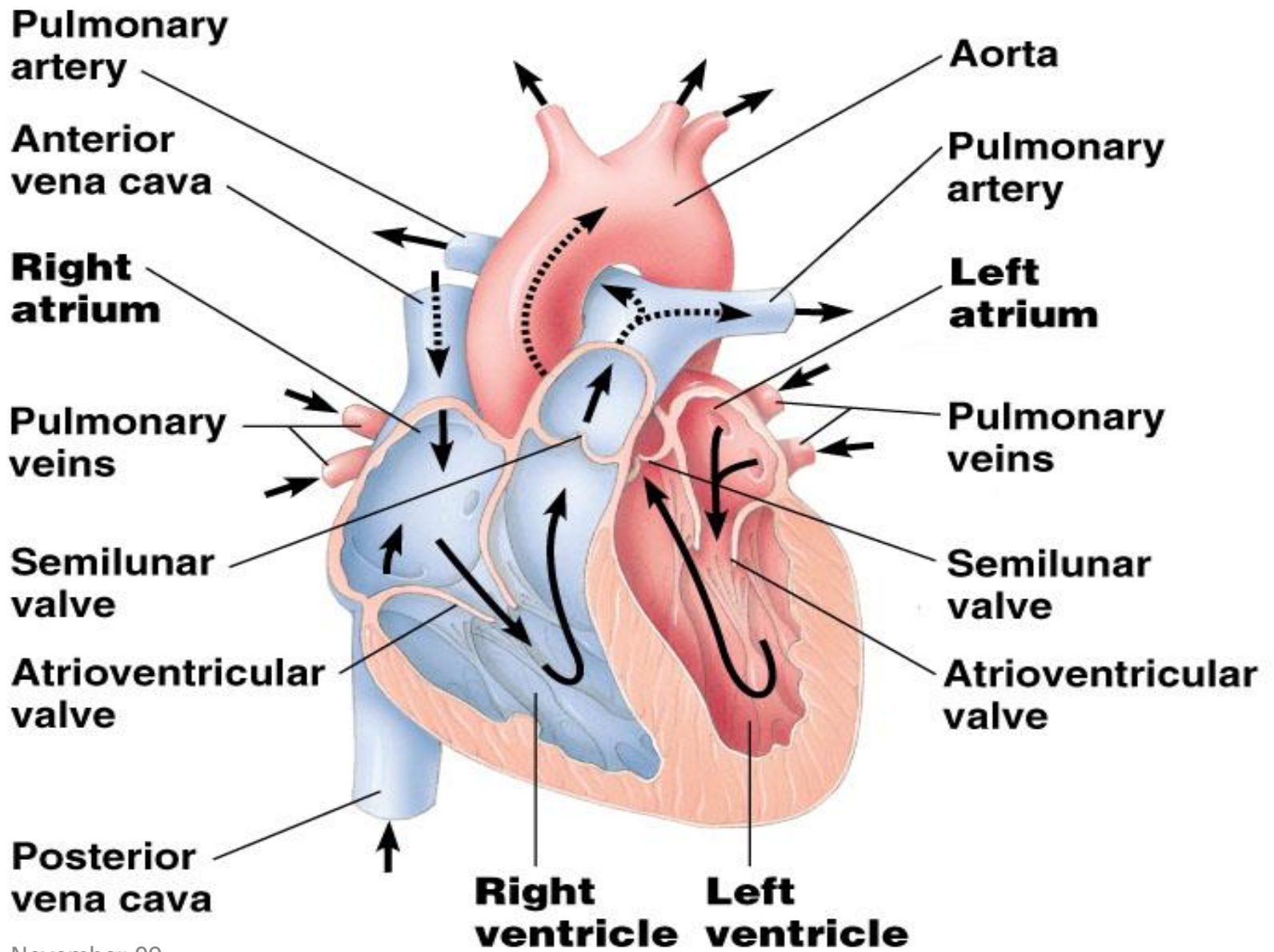
–1. The Heart- cardiac muscle tissue

–highly interconnected cells

–four chambers

- Right atrium
- Right ventricle
- Left atrium
- Left ventricle







Pathway of the blood

- Superior Vena Cava
- Right Atrium
- Tricuspid Valve
- Right Ventricle
- Pulmonary Semilunar Valve
- Lungs
- Pulmonary Vein
- Bicuspid Valve
- Left Ventricle
- Aortic Semilunar Valve
- Aorta



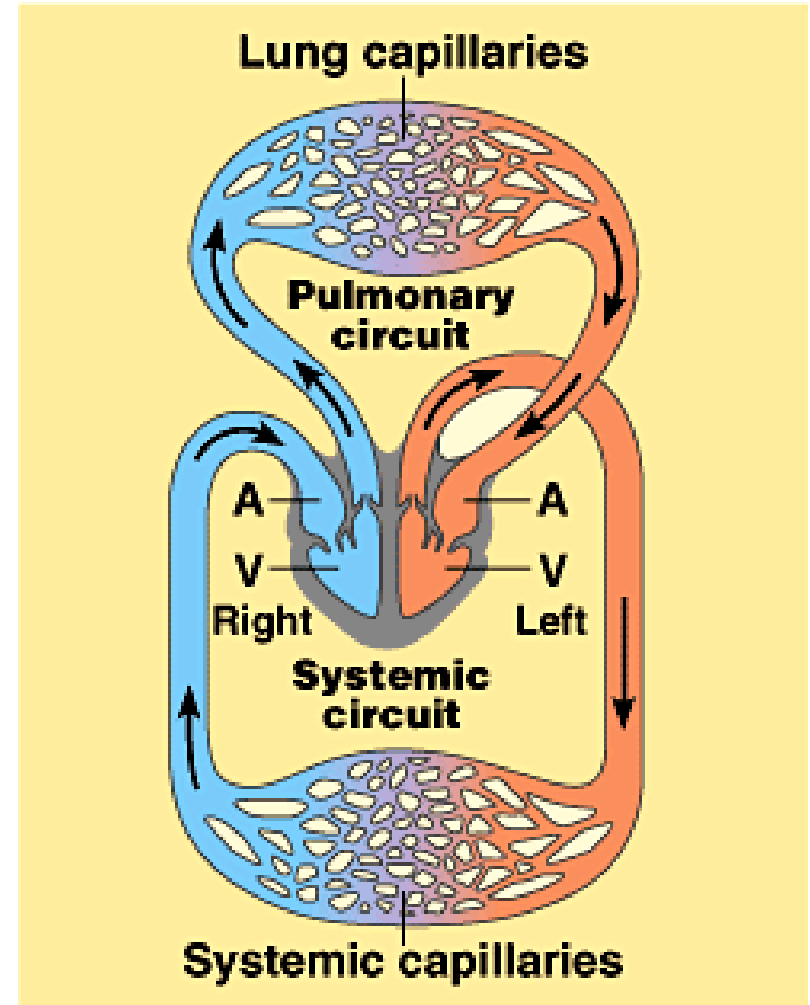
Circuits

► Pulmonary circuit

–The blood pathway between the right side of the heart, to the lungs, and back to the left side of the heart.

► Systemic circuit

–The pathway between the left and right sides of the heart.



(c) Mammal



The Cardiovascular System

2. Blood Vessels -A network of tubes

Arteries → arterioles move away from the heart

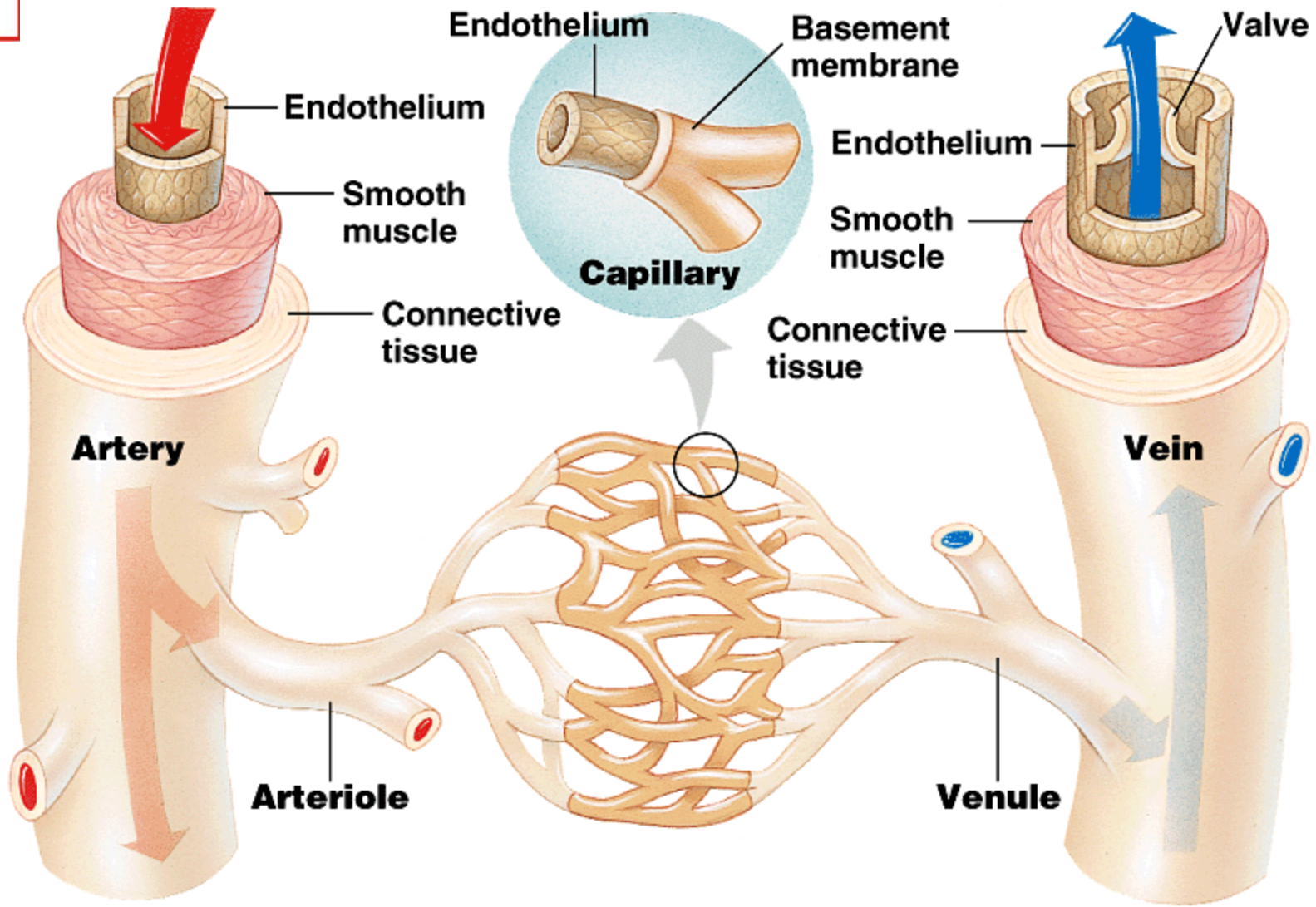
- Elastic Fibers
- Circular Smooth Muscle

Capillaries – where gas exchange takes place.

- One cell thick
- Serves the Respiratory System

Veins → Venules moves towards the heart

- Skeletal Muscles contract to force blood back from legs
- One way valves
- When they break - varicose veins form

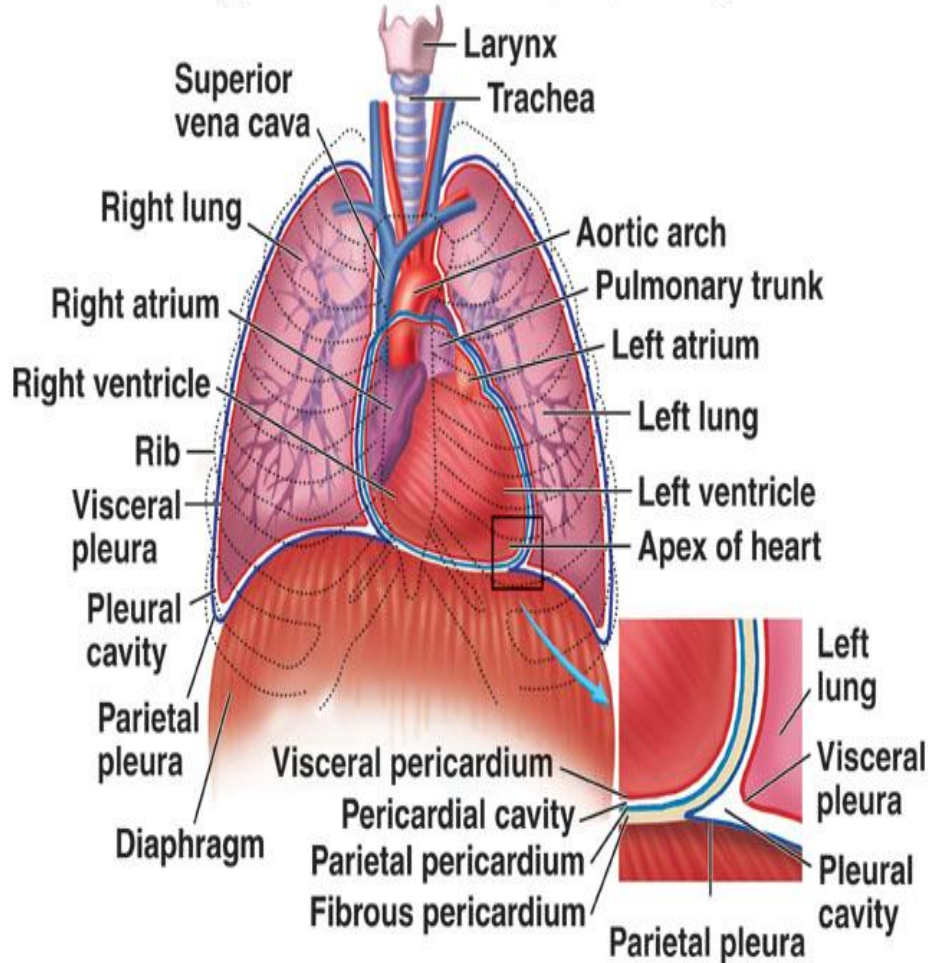


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Size, Shape, Location of the Heart

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- Size of a closed fist
- Shape
 - Apex: Blunt rounded point of cone
 - Base: Flat part at opposite of end of cone
- Located in thoracic cavity in mediastinum



Functions of the cardiovascular system

1. Generating blood pressure
2. Routing blood
3. Ensuring one-way blood flow
4. Regulating blood supply
5. Transport of oxygen from the lungs to the tissues and carbondioxide from the tissues to the lungs where it is excreted.
4. Transport of nutrients (digested food, electrolytes and vitamins) from the gastro-intestinal tract to all parts of the body.



Functions of Cardiovascular System

7. Transport of waste products of cellular metabolism from the tissues to the kidneys and other excretory organs.
8. Transport of hormones from the endocrine glands where they are formed to their target tissues/organs
9. Transport of heat between the body's core and its surfaces thereby aiding temperature regulation.
10. Transport of blood cells.



Heart Wall

Three layers of tissue

Epicardium: This serous membrane of smooth outer surface of heart

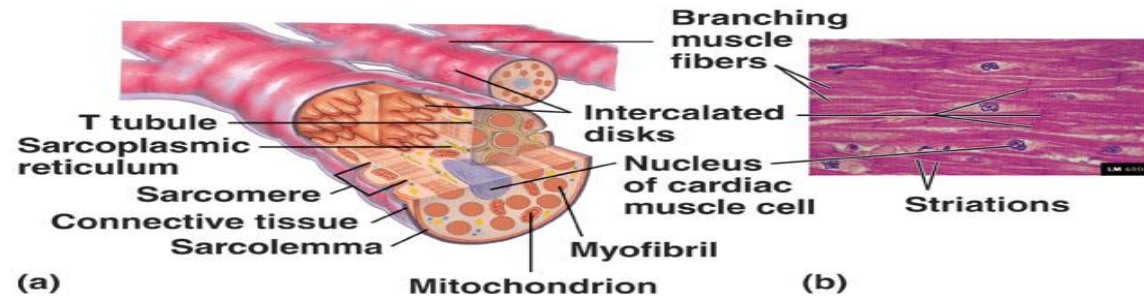
Myocardium: Middle layer composed of cardiac muscle cell and responsibility for heart contracting

Endocardium: Smooth inner surface of heart chambers



Properties of Cardiac Muscles

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- ▶ Elongated, branching cells containing 1-2 centrally located nuclei
- ▶ Contains actin and myosin myofilaments
- ▶ Intercalated disks: Specialized cell-cell contacts
- ▶ Desmosomes hold cells together and gap junctions allow action Potentials.
- ▶ Automaticity – the ability to initiate its own contraction, i.e self excitation
- ▶ Cardiac muscle is a functional syncytium. Electrically, cardiac muscle behaves as single unit
- ▶ Obeys the “all or none” law.
- ▶ Cardiac muscle is not under control of the will like skeletal muscle.



Properties of Cardiac Muscle

- ▶ Double Innervation – sympathetic and parasympathetic nerves. These are cardio-acceleratory and cardio-inhibitory nerves respectively.
- ▶ Absolute refractoriness – this is because the duration of the cardiac action potential (electrical events) is almost as long as the duration of the contraction of the heart muscles (Mechanical events). As a result of this long absolute refractoriness, cardiac muscle cannot be tetanized.



Cell Membrane Potentials

- ▶ **Resting membrane potential (RMP)**
- ▶ Cardiac cells, like all living cells in the body, have an electrical potential across the cell membrane.
- ▶ This potential can be measured by inserting a microelectrode into the cell and measuring the electrical potential in millivolts (mV) inside the cell relative to the outside of the cell.
- ▶ By convention, the outside of the cell is considered 0 mV. If measurements are taken with a resting ventricular myocyte, a membrane potential of about -90 mV will be recorded.



Resting Membrane Potentials

- This **resting membrane potential (E_m)** is determined by the
 1. concentrations of positively and negatively charged ions across the cell membrane,
 2. the relative permeability of the cell membrane to these ions, and
 3. the ionic pumps that transport ions across the cell membrane.



Equilibrium Potentials

- ▶ Of the many different ions present inside and outside of cells, the concentrations of Na, K, Cl, and Ca are most important in determining the membrane potential across the cell membrane.
- ▶ Of the four ions, K is the most important in determining the resting membrane potential. In a cardiac cell, the concentration of K is high inside and low outside the cell.
- ▶ Therefore, a **chemical gradient** (concentration difference) exists for K to diffuse out of the cell. The opposite situation is found for Na; its chemical gradient favors an inward diffusion.
- ▶ The concentration differences across the cell membrane for these and other ions are determined by the activity of energy-dependent ionic pumps and the presence of impermeable.
- ▶ negatively charged proteins within the cell that affect the passive distribution of cations and anions.



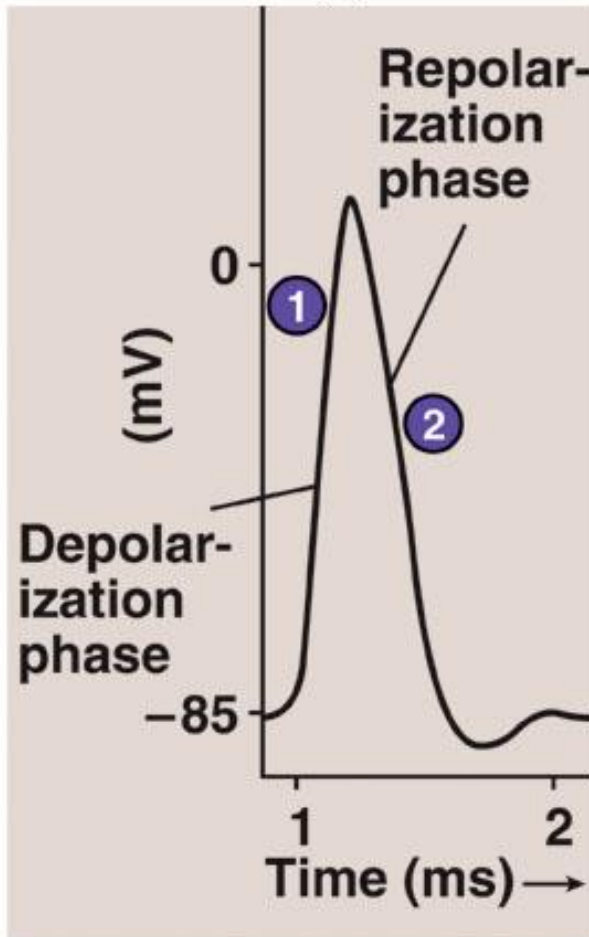
Action Potentials

- ❖ Action potentials occur when the membrane potential suddenly depolarizes and then repolarizes back to its resting state. The two general types of cardiac action potentials include
 - ▶ Non-pacemaker
 - ▶ Pacemaker action potentials.

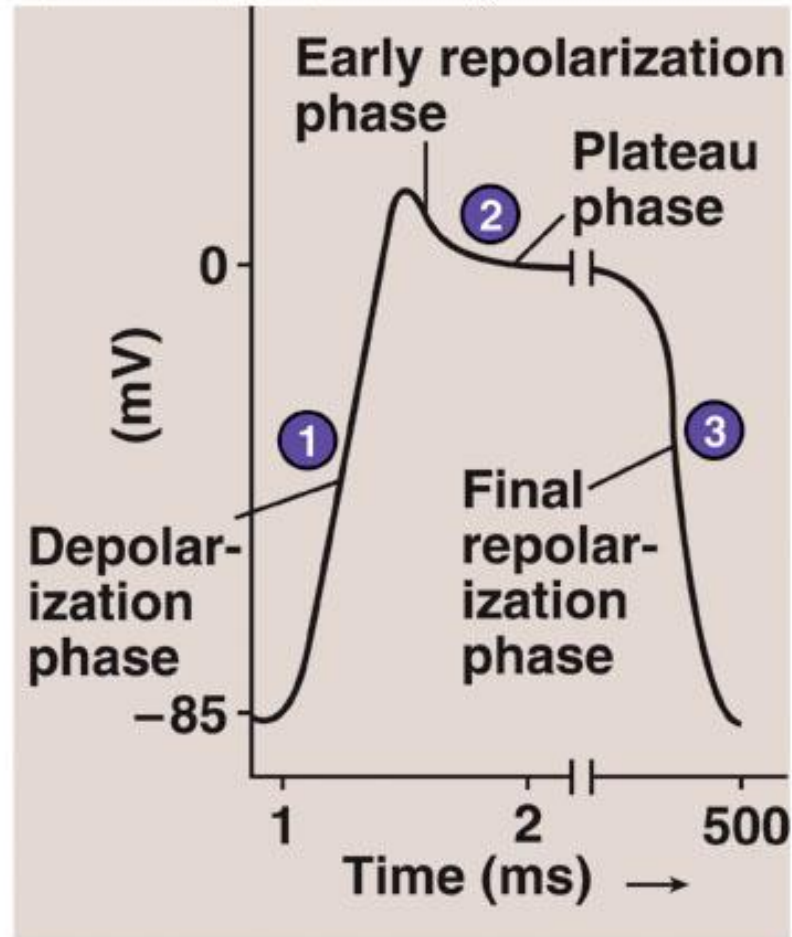


Action Potentials in Skeletal and Cardiac Muscle

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(a)

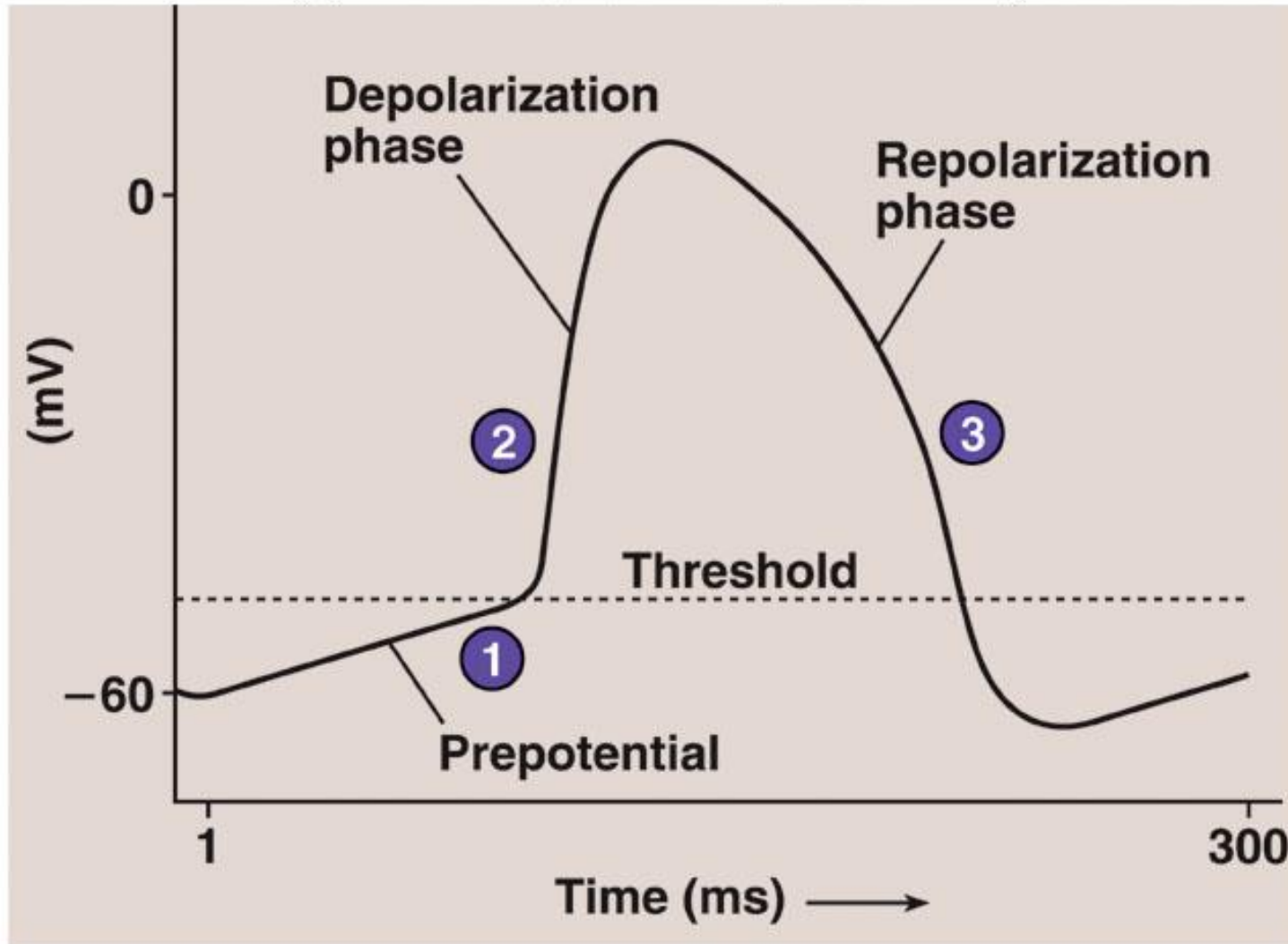


(b)



SA Node Action Potential

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Action Potentials

1. When these cells are rapidly depolarized from -90 mV to a threshold voltage of about -70 mV (owing to, for example, an action potential conducted by an adjacent cell), a rapid **depolarization (phase 1)** is **initiated by a transient increase in fast Na-channel conductance**.
2. **Phase 2 represents an initial repolarization caused by the opening of a special type of K channel (transient outward) and the inactivation of the Na channel.** However, because of the large increase in slow inward Ca, the repolarization is delayed and the action potential reaches a **plateau phase (phase 2)**. **This inward calcium** movement is through long-lasting (Ltype) calcium channels that open when the membrane potential depolarizes to about -40 mV. L-type calcium channels are the major calcium channels in cardiac and vascular smooth muscles.



Action Potentials

• **Repolarization (phase 3) occurs** when K increases through delayed rectifier potassium channels and Ca decreases. Therefore, changes in Na, Ca, and K conductances primarily determine the action potential in nonpacemaker cells.



Refractory Period

During phases 1, 2, and part of phase 3, the cell is refractory (i.e., unexcitable) to the initiation of new action potentials. This is the **effective refractory period (ERP)**. Cardiac muscle cell completely insensitive to further stimulation.

The ERP acts as a protective mechanism in the heart by limiting the frequency of action potentials (and therefore contractions) that the heart can generate. This enables the heart to have adequate time to fill and eject blood. The long ERP also prevents the heart from developing sustained, tetanic contractions like those that occur in skeletal muscle.



Refractory Period

- ▶ At the end of the ERP, the cell is in its **relative refractory period**. **Early in this period, suprathreshold** depolarization stimuli are required to elicit action potentials.
- ▶ When the sodium channels are fully recovered, the cell becomes fully excitable and normal depolarization stimuli can elicit new, rapid action potentials.



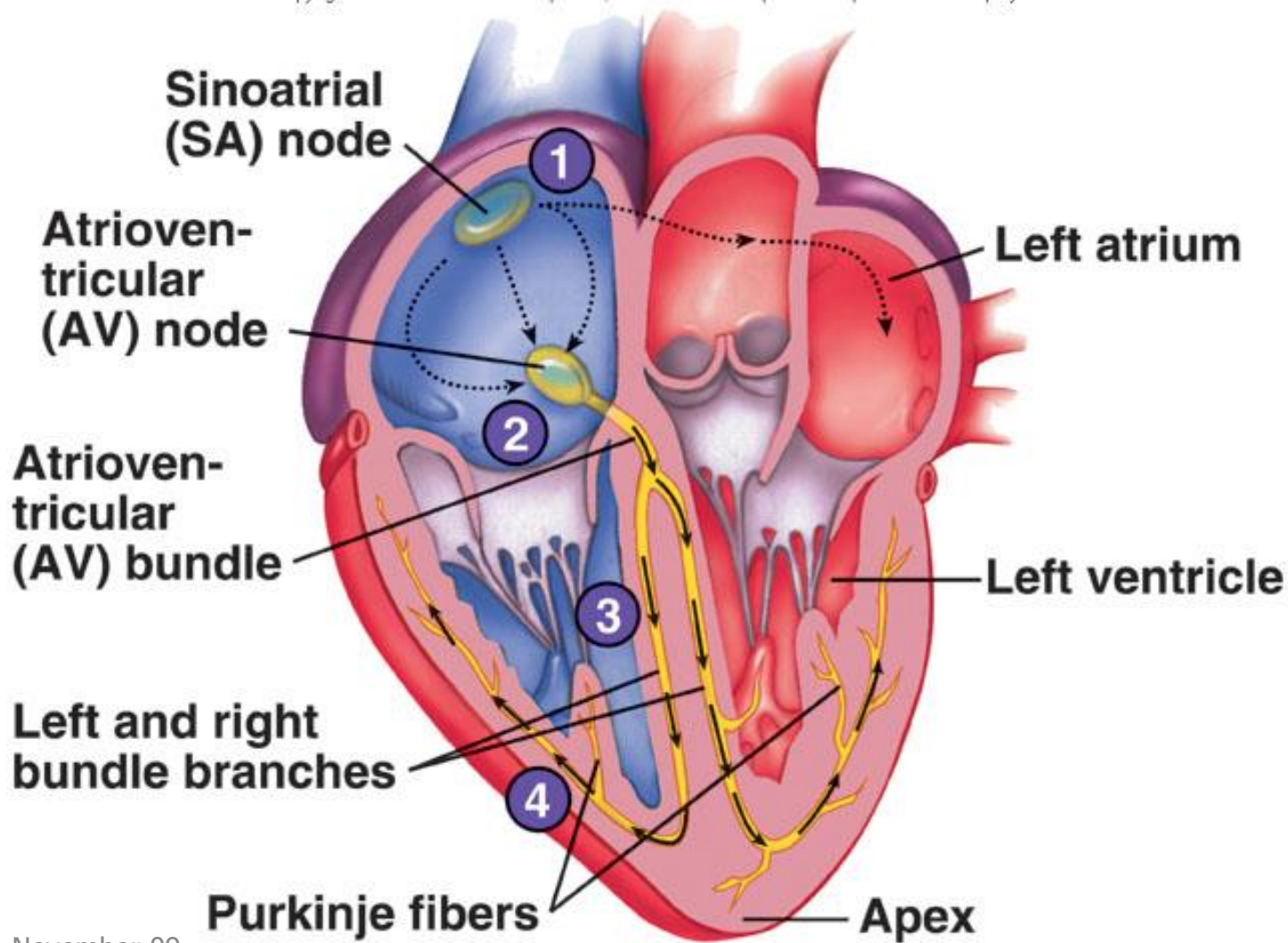
Conduction of Action Potentials within the Heart

- ▶ The action potentials generated by the SA node spread throughout the atria primarily through cell-to-cell conduction
- ▶ When a single myocyte depolarizes, positive charges accumulate just inside the sarcolemma. Because individual myocytes are joined together by low-resistance **gap junctions** located at the **intercalated disks**, ionic currents can flow between two adjoining cells.
- ▶ When these ionic intercellular currents are sufficient to depolarize the adjoining cell to its threshold potential, an action potential is elicited in the second cell.



Conducting System of Heart

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Conduction System of the Heart

- ▶ As each wave of action potentials originating from the **SA** node spreads across and depolarizes the atrial muscle, it initiates excitation-contraction coupling.

- ▶ Action potentials normally have only one pathway available to enter the ventricles, a specialized region of cells called the **atrioventricular (AV) node**.



Conduction Systems of the Heart

▶ Action potentials leaving the AV node enter the base of the ventricle at the **bundle of His** and then follow the left and right **bundle branches along the interventricular septum**. These specialized bundle branch fibers conduct action potentials at a high velocity (about 2 m/sec).

▶ The bundle branches divide into an extensive system of **Purkinje fibers that conduct** the impulses at high velocity (about 4 m/sec) throughout the ventricles. The Purkinje fiber cells connect with ventricular myocytes, which become the final pathway for cell-to-cell conduction within the heart



Electrocardiogram

- Action potentials through myocardium during cardiac cycle produces electric currents that can be measured

- Pattern

P wave

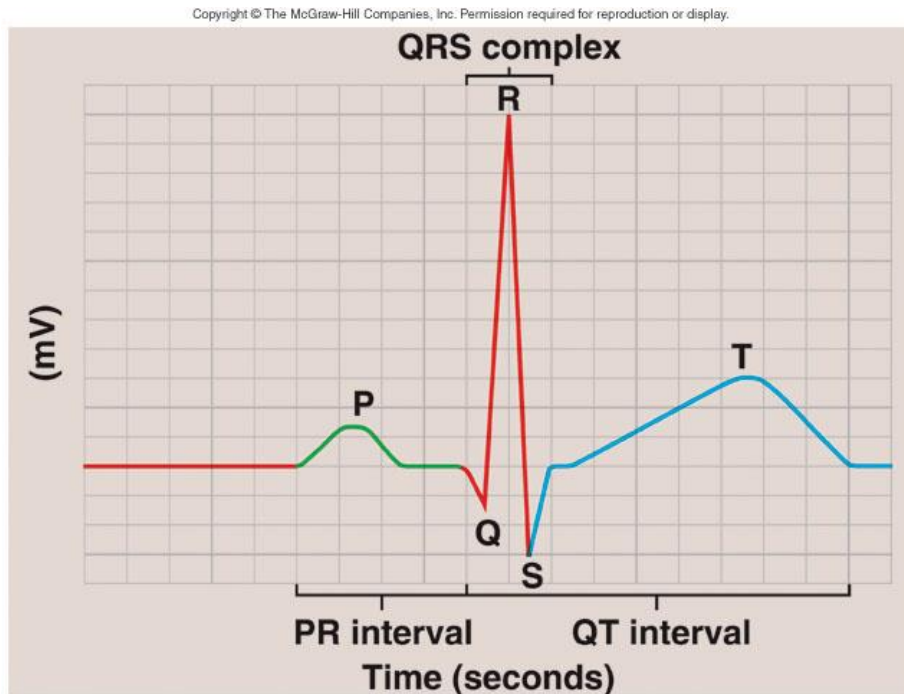
- Atria depolarization

QRS complex

- Ventricle depolarization
- Atria repolarization

T wave:

- Ventricle repolarization





Interpretation of Normal and Abnormal Cardiac Rhythms from the ECG

- ❑ One important use of the ECG is that it lets a physician evaluate abnormally slow, rapid, or irregular cardiac rhythm.
 - ▶ **Atrial flutter** (250-350 beats/min)
 - ▶ **Atrial fibrillation**
 - ▶ **First-degree AV nodal block**
 - ▶ **Second-degree AV nodal block**
 - ▶ **Third degree AV nodal block**
 - ▶ **Ventricular tachycardia** (100–200 beats/min)
 - ▶ **Ventricular flutter** (greater than 200 beats/min).
 - ▶ **Ventricular fibrillation**
 - ▶ **Premature Depolarizations**

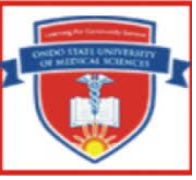


ECG Leads: Placement of Recording Electrodes

The ECG is recorded by placing an array of electrodes at specific locations on the body surface. Conventionally, electrodes are placed on each arm and leg, and six electrodes are placed at defined locations on the chest.

Three basic types of ECG leads are recorded by these electrodes:

- ▶ Standard limb leads,
- ▶ Augmented limb leads, and
- ▶ Chest leads.



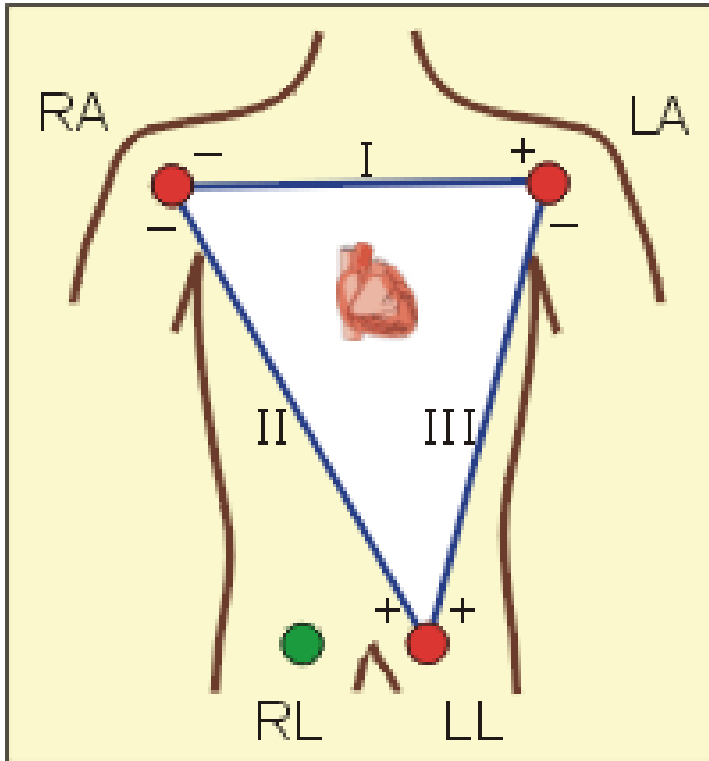
Standard Limb Leads

Lead I has the **positive electrode on the left arm** and the **negative electrode on the right arm**, therefore measuring the potential difference across the chest between the two arms.

lead II the positive electrode is on the left leg and the negative electrode is on the right arm.

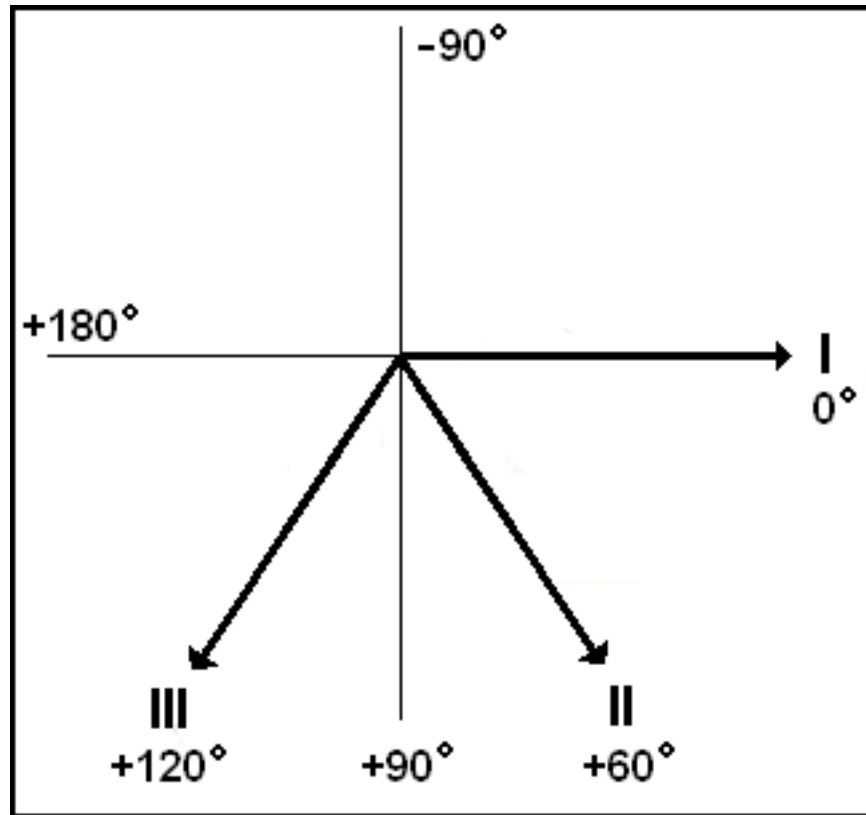
Lead III has the **positive** electrode on the left leg and the negative electrode on the left arm.

Standard Limb Lead



Einthoven Triangle -
equilateral triangle with
heart at centre.

Standard Limb Leads





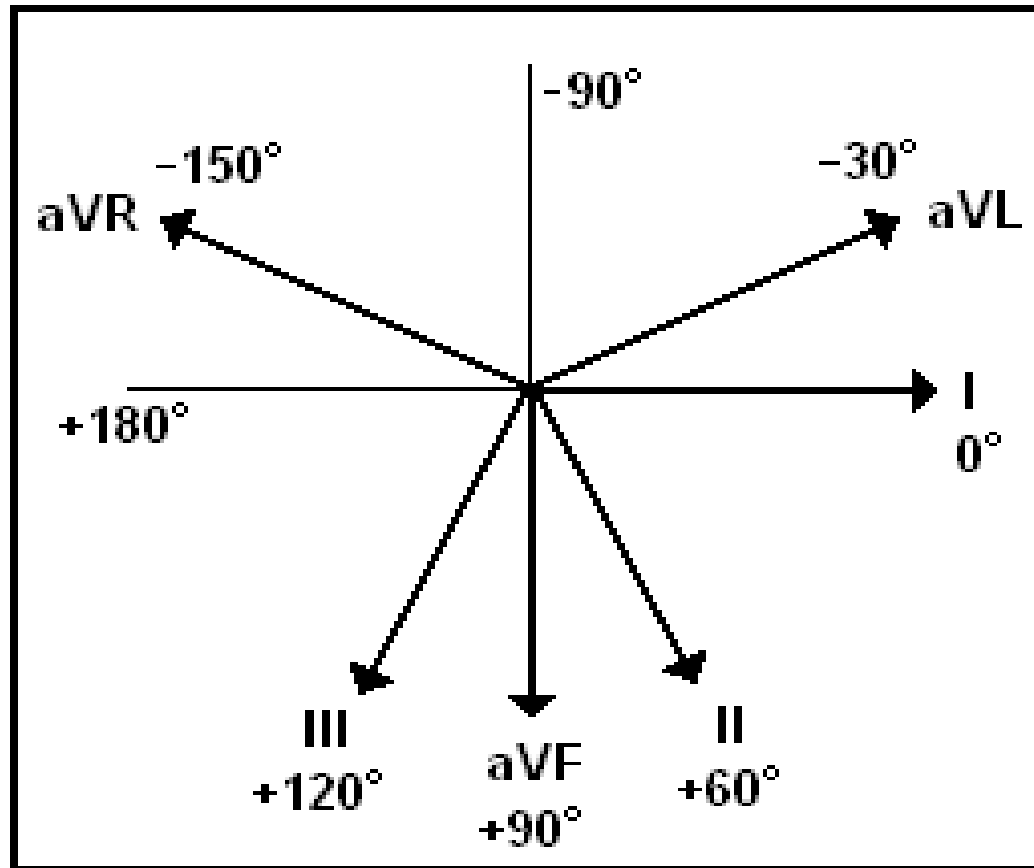
Augmented Limb Leads

Three **augmented limb leads exist in addition** to the three bipolar limb leads described.

Each of these leads has a single positive electrode that is referenced against a combination of the other limb electrodes.

The positive electrodes for these augmented leads are located on the left arm (aVL), the right arm (aVR), and the left leg (aVF; the “F” stands for “foot”).

All Limb Leads

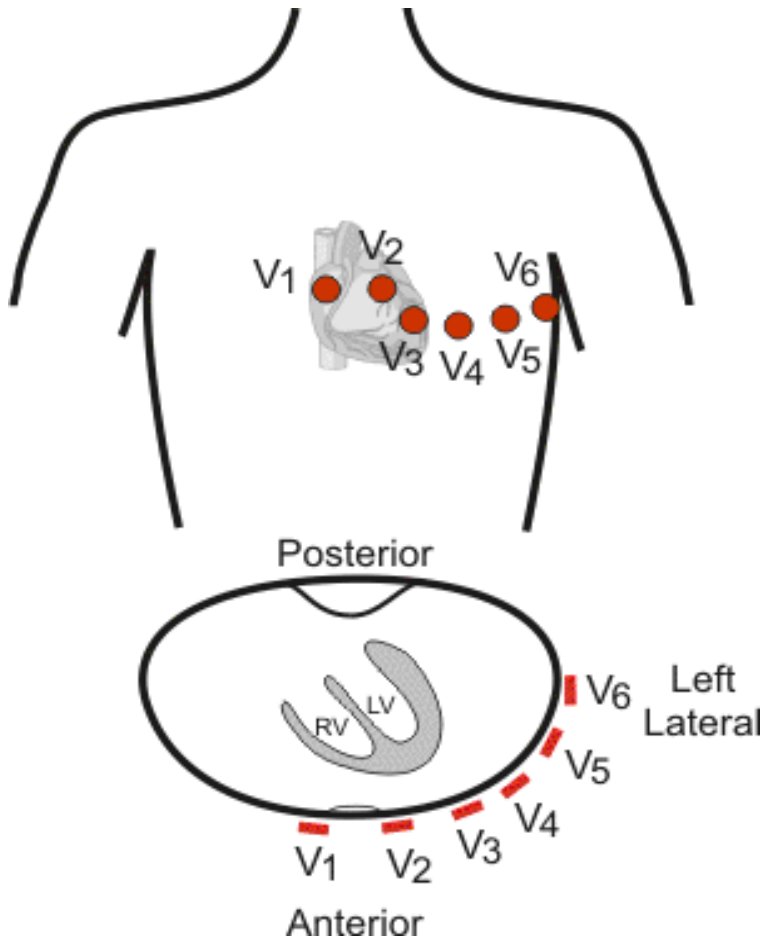




ECG Chest Leads

- The last ECG leads to consider are the unipolar, precordial **chest leads. These six positive** electrodes are placed on the surface of the chest over the heart to record electrical activity in a horizontal plane perpendicular to the frontal plane. The six leads are named V1–V6.
- V1 is located to the right of the sternum over the fourth intercostal space.
- V6 is located laterally (midaxillary line) on the chest over the fifth intercostal space.

ECG Chest Leads



Leads V1 and V2 view antero-septal region.

V3 and V4 view antero-apical region.

V5 and V6 view antero-lateral region.

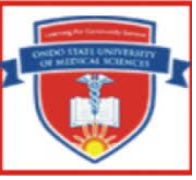
ECG Chest Leads

8. Apply electrode paste and attach electrodes to the chest:

- V_1 —4th intercostal space (ICS) at right sternal border. Females: Choose a site as close to standard position as possible.
- V_2 —4th ICS at left sternal border.
- V_3 —Midway between V_2 and V_4 .
- V_4 —5th ICS at midclavicular line.
- V_5 —Left anterior axillary line at level of V_4 horizontally.
- V_6 —Left midaxillary line at level of V_4 horizontally (see Figure 11-1-4).

8. Promotes proper display of ECG on paper.

- In females, whose breast tissue obscures sternal border.



Cardiac Cycle

The cardiac cycle is divided into two general categories: systole and diastole.

▶ **Systole refers** to events associated with ventricular contraction and ejection.

▶ **Diastole refers to the rest** of the cardiac cycle, including ventricular relaxation and filling.

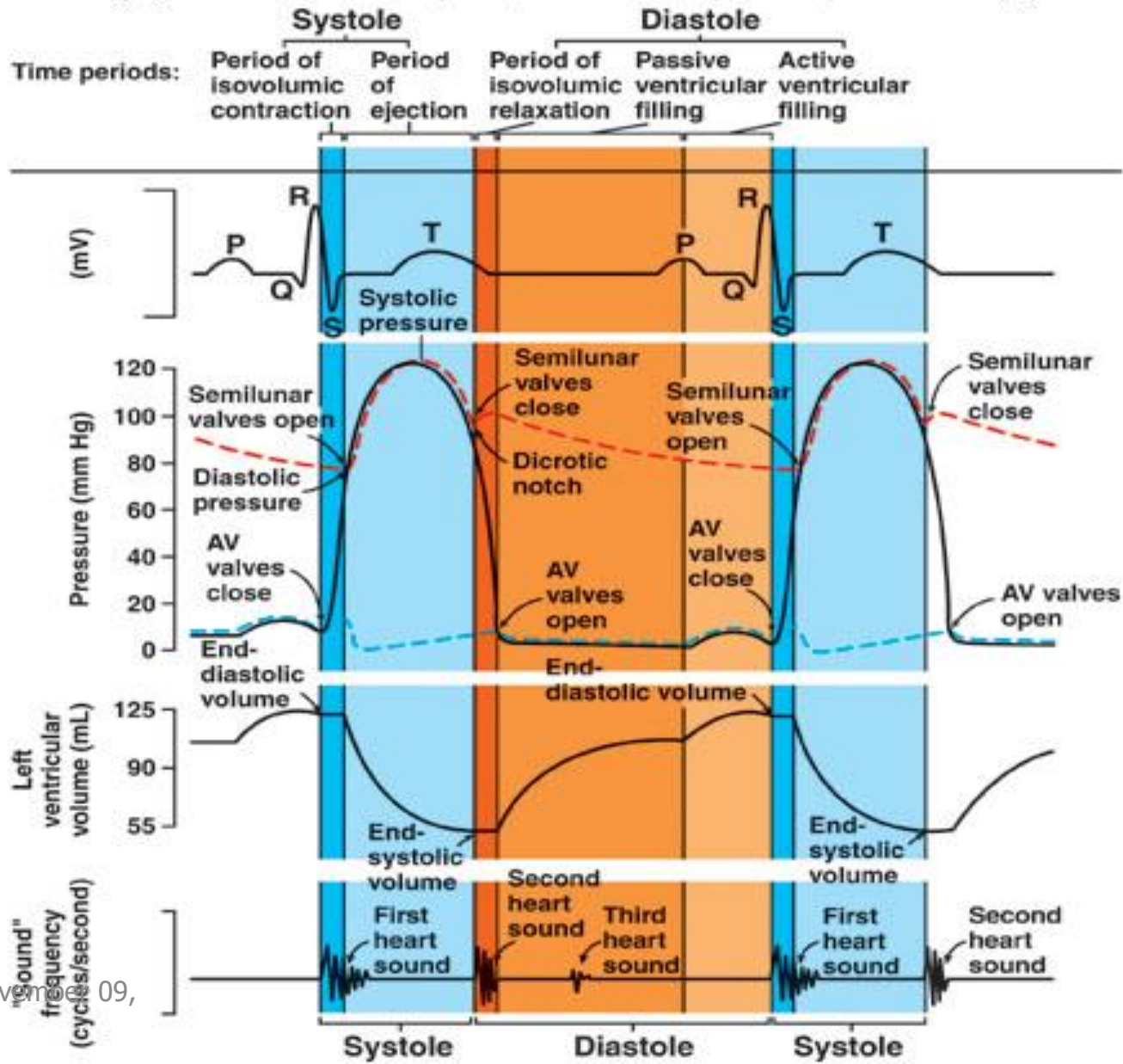
❖ The cardiac cycle is further divided into seven phases, beginning when the P wave appears. These phases are

- Atrial systole
- Isovolumetric contraction,
- Rapid ejection,
- Reduced ejection,
- Isovolumetric relaxation,
- Rapid filling, and
- Reduced filling.



Events during Cardiac Cycle

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Heart Sounds

➤ First heart sound or “lubb”

Atrioventricular valves and surrounding fluid vibrations as valves close at beginning of ventricular systole

➤ Second heart sound or “dupp”

Results from closure of aortic and pulmonary semilunar valves at beginning of ventricular diastole, lasts longer

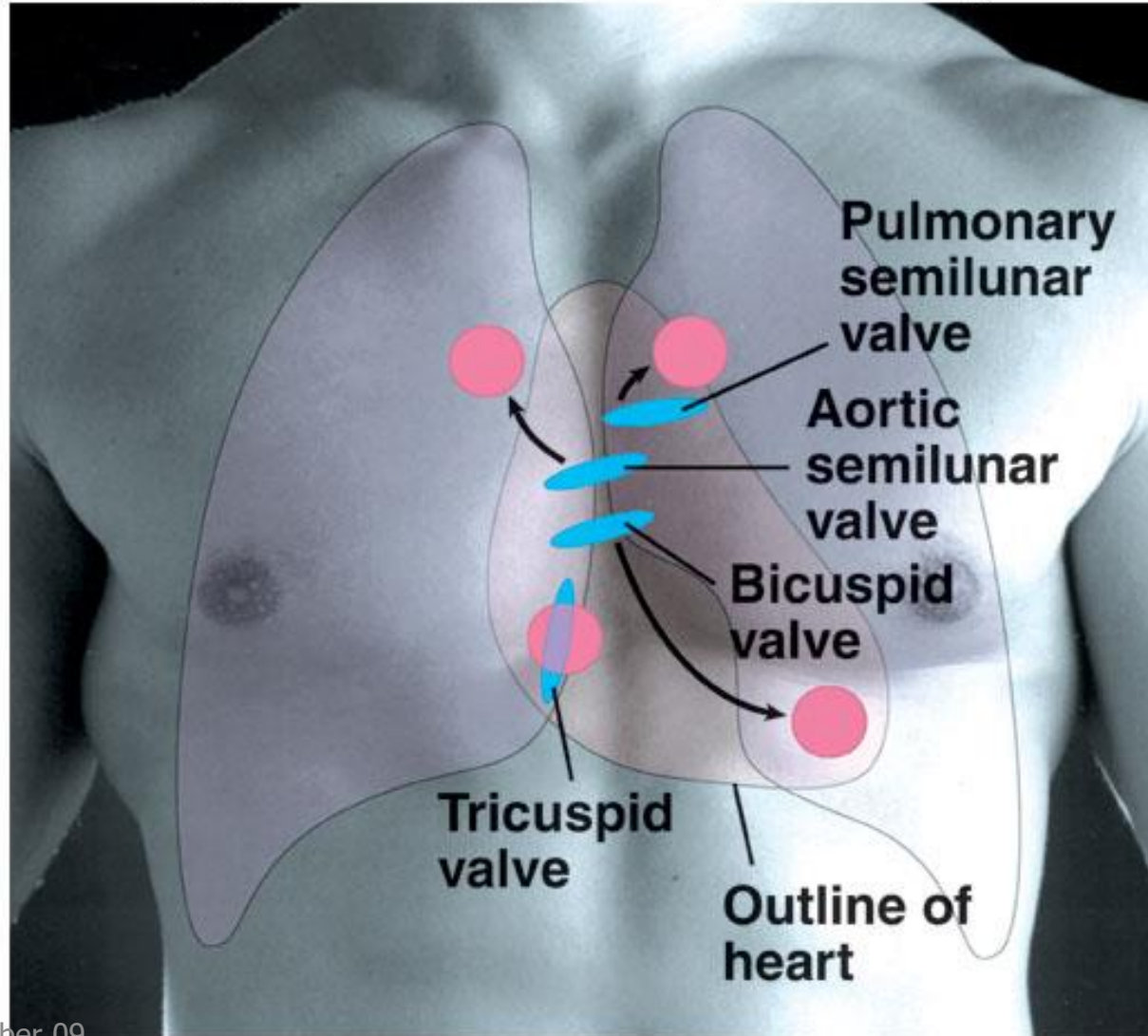
➤ Third heart sound (**occasional**)

Caused by turbulent blood flow into ventricles and detected near end of first one-third of diastole



Location of Heart Valves

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Disorders of the Cardiovascular System

- **Anemia** - lack of iron in the blood, low RBC count
- **Leukemia** - white blood cells proliferate wildly, causing anemia
- **Hemophilia** - bleeder's disease, due to lack of fibrinogen in thrombocytes
- **Heart Murmur** - abnormal heart beat, caused by valve problems
- **Heart attack** - blood vessels around the heart become blocked with plaque, also called *myocardial infarction*

Thank you