Introduction to Heamodynamics & Electro-cardiac Physiology

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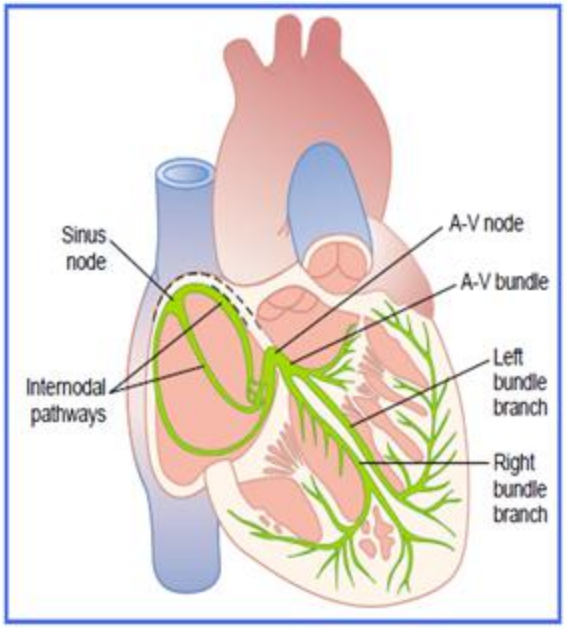
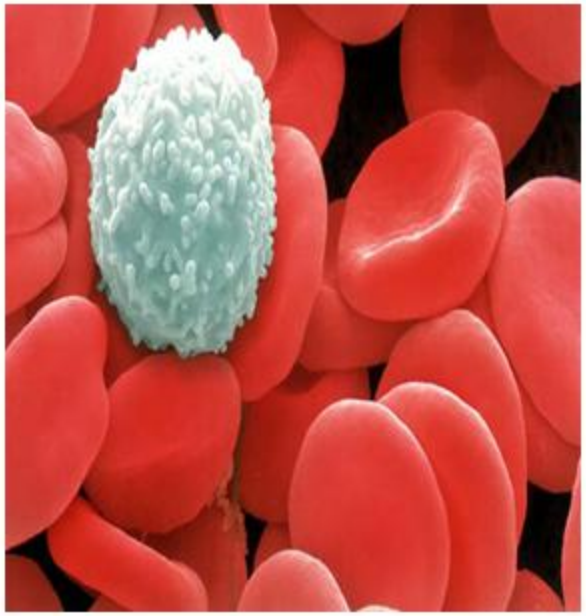
HEAMODYNAMICS





Hemodynamics is a physical and physiological principles of blood flow (circulatory system) in the body.

Blood Composition

- Approx 45% by Vol. Solid Components
  - » Red Blood Cells (12μm x 2 μm)
  - » White Cells
  - » Platelets
- Approx 55% Liquid (plasma)
  - » 91.5% of which is water
  - » 7% plasma proteins
  - » 1.5% other solutes

Blood Functions

- Transportation of blood gases, nutrients, wastes
- Homeostasis (regulation) of P^{H}, Body Temp, water content
- Protection

The forces involved with the movement of blood throughout the human circulatory system include:

1. **Kinetic and potential energy provided by the cardiac pump**
2. **Gravity**
3. **Hydrostatic Pressure** (weight of the liquid acting on a unit area at that depth plus any pressure acting on the surface of the liquid)
4. **Pressure gradients or differences between two any points**

- **Properties of blood itself that affect its flow:**
    1. Viscosity
    2. Inertial mass **(mass of an object measured by its resistance to acceleration)**
    3. Volume of blood to be moved
- **Factors that affect the motion of blood through the vascular channels include:**
    1. Size of blood vessel
    2. Condition of blood vessel
    3. Smoothness of lumen
    4. Elasticity of muscular layer (tunica media)
    5. Destination of blood (distal vascular bed)

PRESSURE : force per unit area.

Units : Newtons/m^2, pascal (Pa), atmospheres(atm), mmHg.

FLOW RATE: Amount of fluid passing a given point over a given period of time

VISCOSITY: The internal friction between adjacent layers of fluid.

Blood is 1.5 times as viscous as water and its viscosity.

KINETIC ENERGY: active energy , the energy of motion as the forward movement of blood, It is transferred into potential energy when it produces a lateral pressure or stretching of vessel walls during systole

POTENTIAL ENERGY: stored energy, it is converted back into kinetic energy when the arterial walls rebound during diastole

Cardiac Output

- Flow of blood is usually measured in l/min
- Total amount of blood flowing through the circulation = *Cardiac Output (CO)*

Cardiac Ouput = *Stroke Vol.* x *Heart Rate*

= *5 l/min*

Influenced by **Blood Pressure** & **Resistance**

Force of blood against vessel wall

↑ with water retention
↓ with dehydration, hemorrage

- **Blood viscosity**
- **Vessel Length**
- **Vessel Elasticity**
- **Vasconstriction / Vasodilation**

Blood Pressure

Driving force for blood flow is pressure created by ventricular contraction

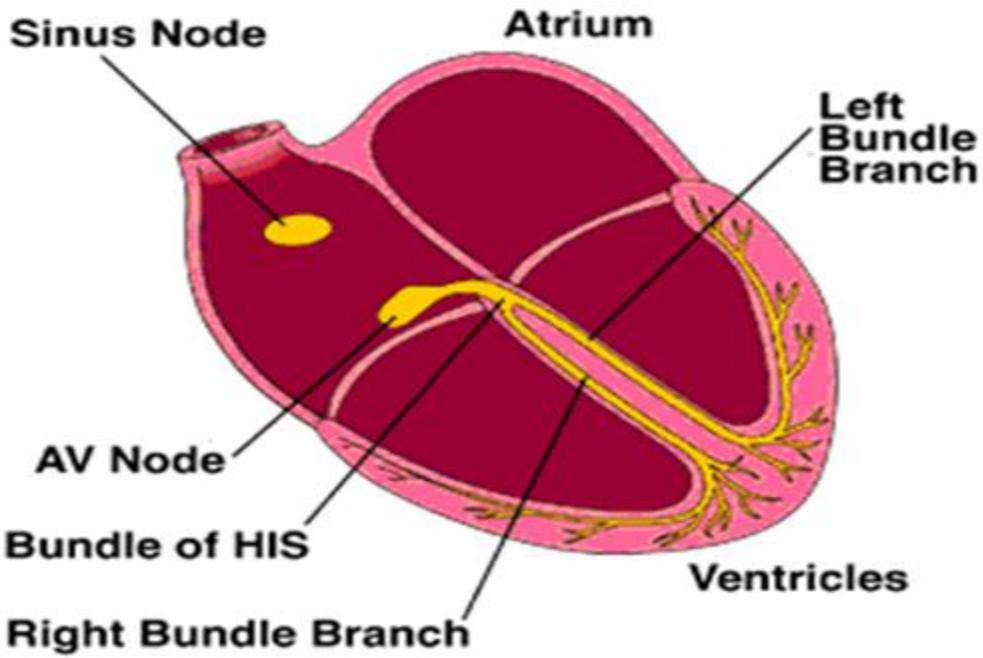
Elastic arterial walls expand and recoil to allow the continuous blood flow

Blood pressure is highest in the arteries and falls continuously . . .

Systolic pressure in Aorta: 120 mm Hg

Diastolic pressure in Aorta: 80 mm Hg

ELECTRO-CARDIAC PHYSIOLOGY



The **main functions** of the heart is to pump blood through two circuits:

- ***Pulmonary circuit*** through the lungs to oxygenate the blood and remove carbon dioxide
- ***Systemic circuit*** to deliver oxygen and nutrients to tissues and remove carbon dioxide

➢ **A dual pump**

In order to beat, the heart needs three types of cells

- **Rhythm generators**, produce an electrical signal- **SAN / pacemaker**
- **Conductors** to spread the pacemaker signal
- **Contractile cells** (myocardium) to mechanically pump blood

Properties of Myocardial cells :

- Automaticity, Excitability, Conductivity, Contractility

KEY TERMS:

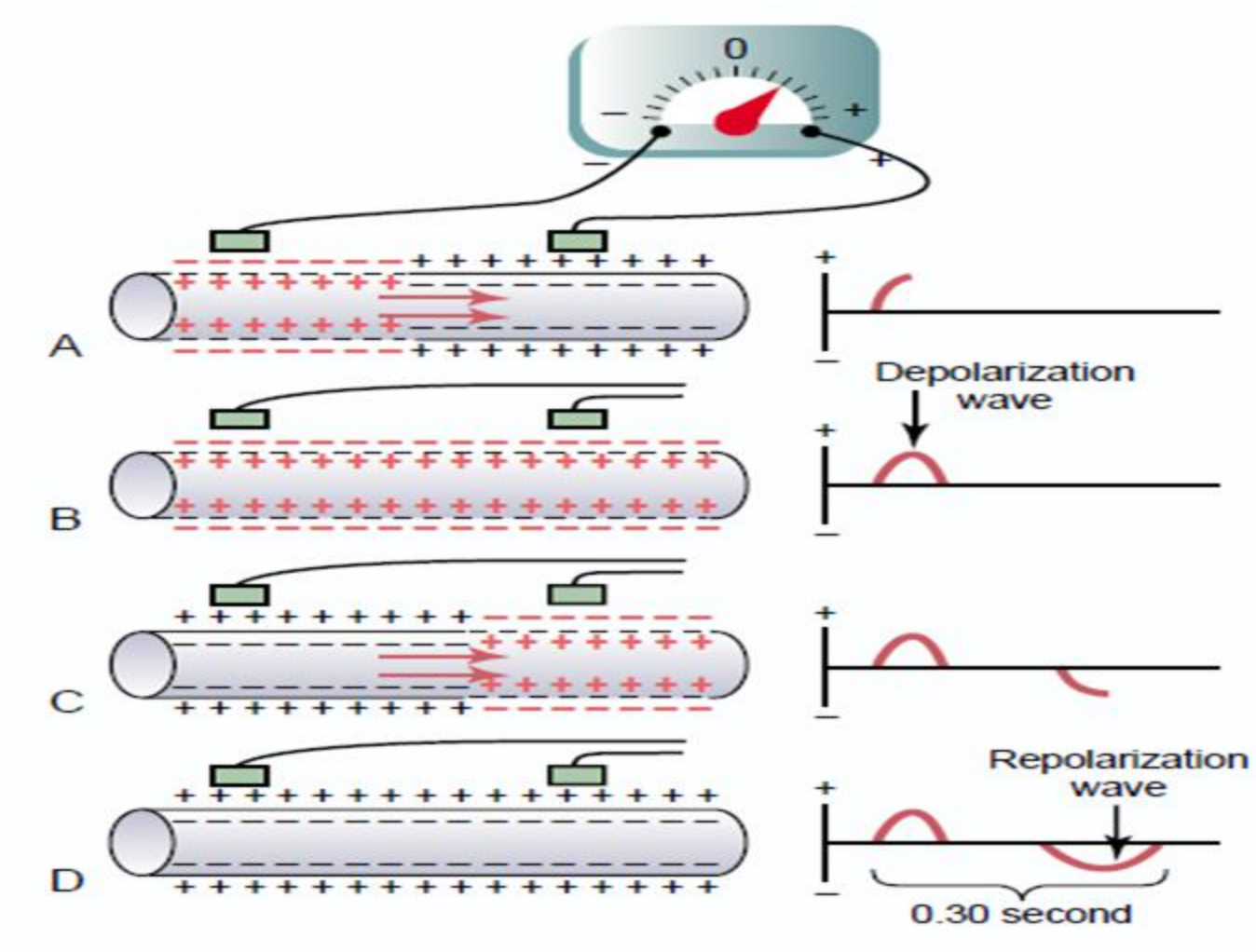
Depolarization:

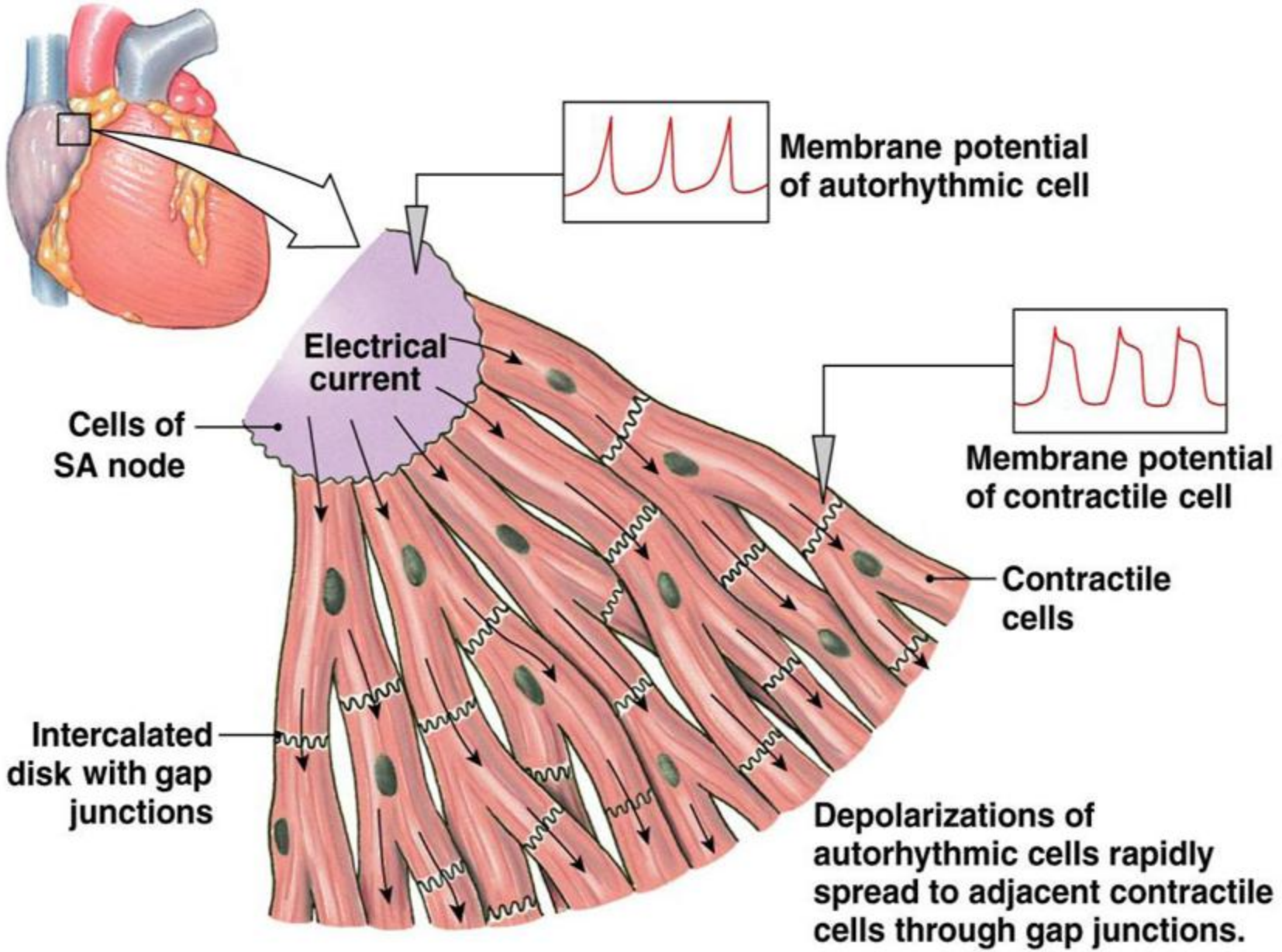
- Movement of ions (Na^{2+}, K^{+} and Ca^{2+}) across cell membrane causing ***inside of cell to become more positive;*** an electrical event which is expected to **result in a contraction** (mechanical event). A difference between electrical charges must exist for electrical current to be generated.
- This electrical activity appears on a ECG as wave forms.

Repolarization:

- Movement of ions across cell membrane in which the ***inside of cell is restored to its negative charge***.

Recording the depolarization wave (A and B) and the repolarization wave (C and D) from a cardiac muscle fiber.




Membrane potential of autorhythmic cell
Electrical current
Cells of SA node
Membrane potential of contractile cell
Contractile cells
Intercalated disk with gap junctions
Depolarizations of autorhythmic cells rapidly spread to adjacent contractile cells through gap junctions.

Electrical Conduction in Myocardial Cells

- **Pacemaker cells** initiate rhythmic depolarization autonomously.
- Another set of non-contractile cells **(conducting fibers)** rapidly conduct depolarization to all parts of the heart and thus coordinate contraction throughout the heart. The result is **nearly synchronous contraction of all muscle fibers within each chamber**.

Important structures in which these conducting muscle cells are located:

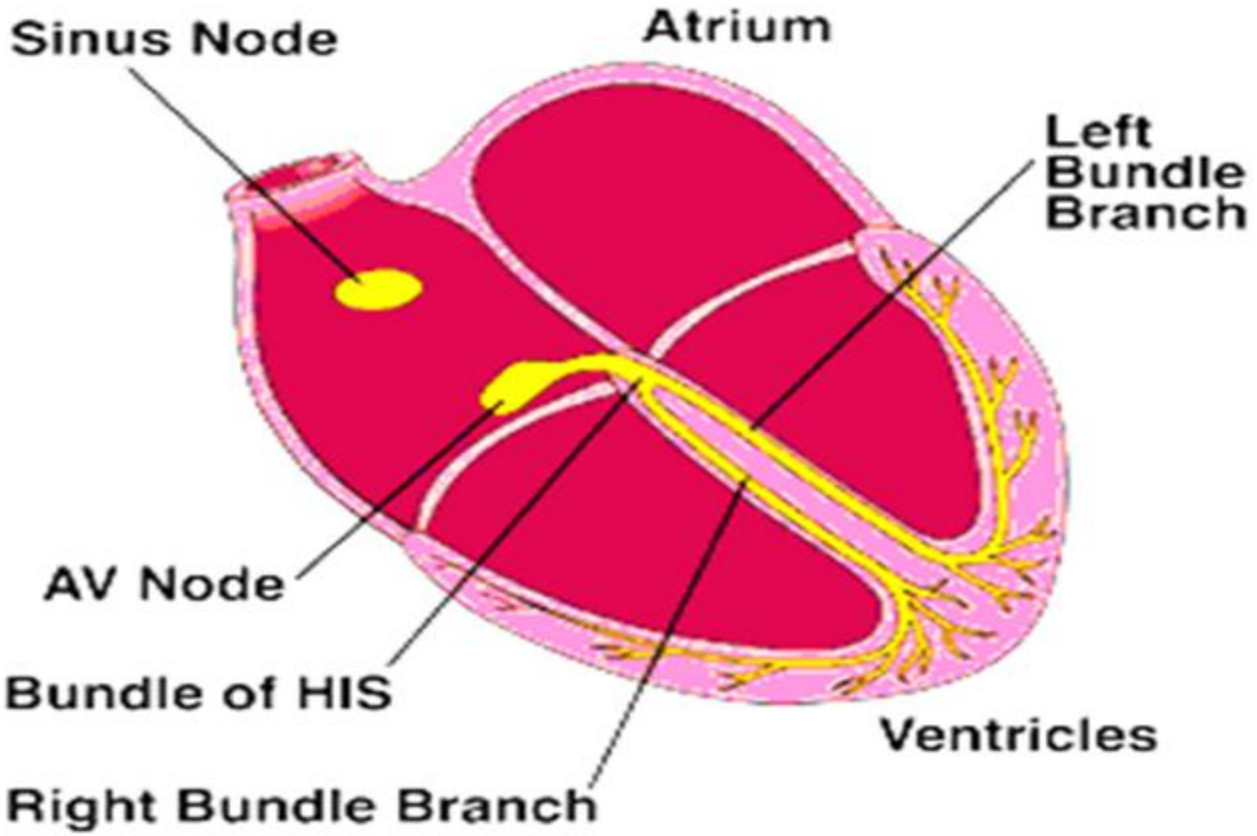
- **Sino-atrial node**
- **AV node**
- **Bundle of His**
- **Purkinje fibers in the endocardium**

Each of the conducting structures rhythmically depolarizes and generates action potentials at its own intrinsic rate. Once one of these cells depolarizes, the entire chamber depolarizes, because cardiac muscle cells are electrically coupled.

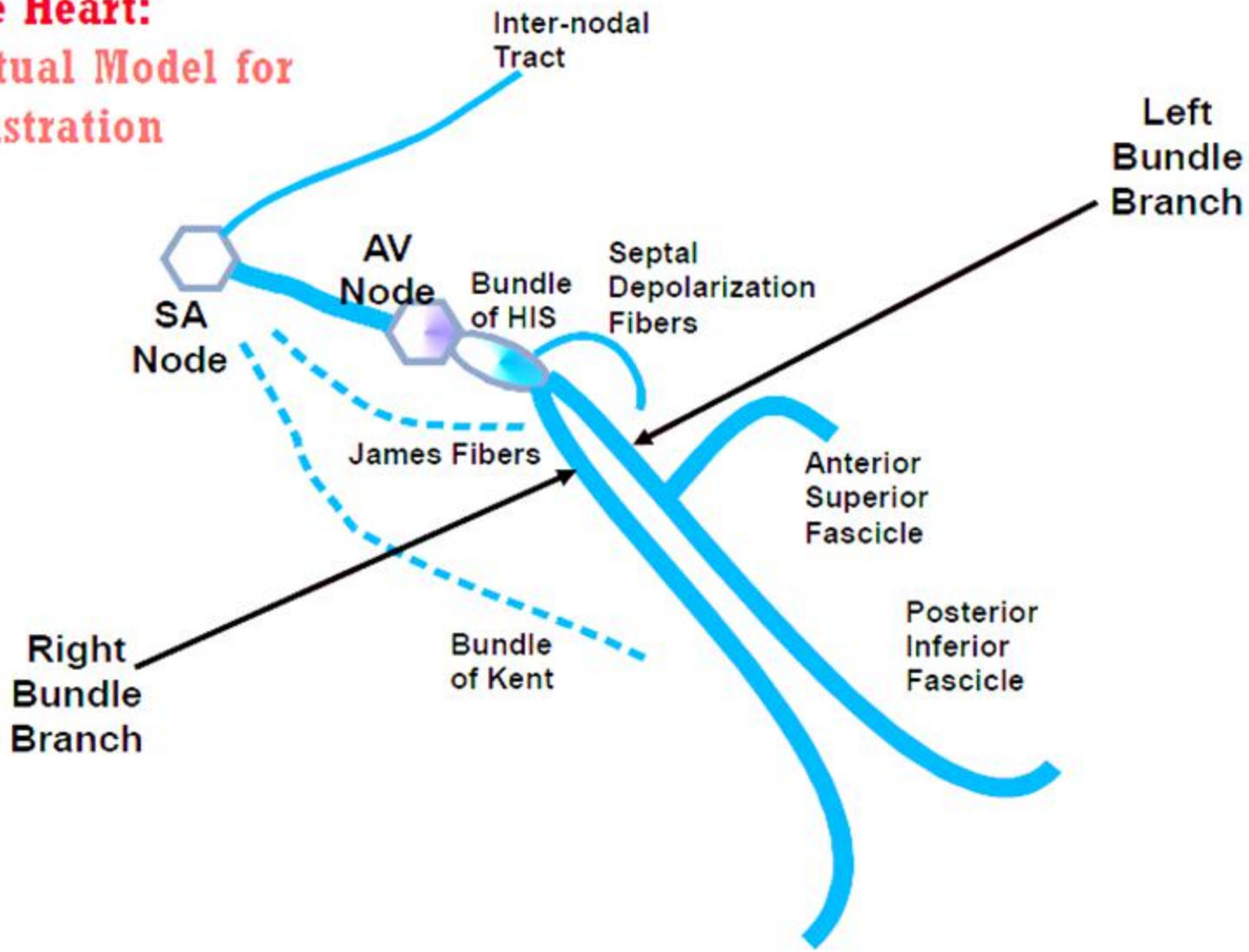
In normal function, depolarization is conducted through the specialized muscle fibers from the right atrium to the rest of the heart.

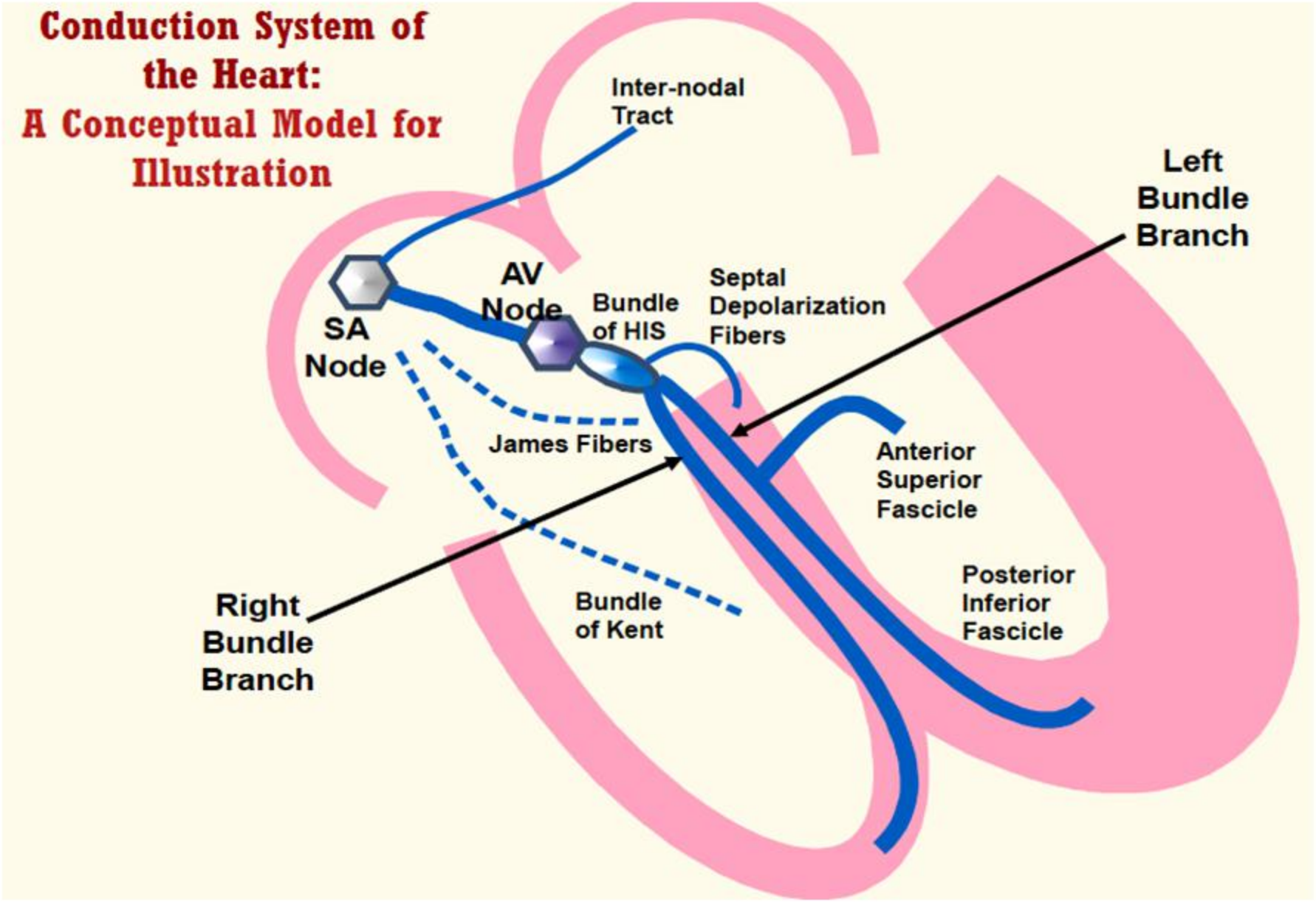
- **Under normal conditions, the PACEMAKER is the sino-atrial node, because it depolarizes with the highest frequency.**
- **If the sino-atrial node slows down for some reason, other portions of the conduction system will take over the pacemaker activity**

Normal Cardiac Rhythm

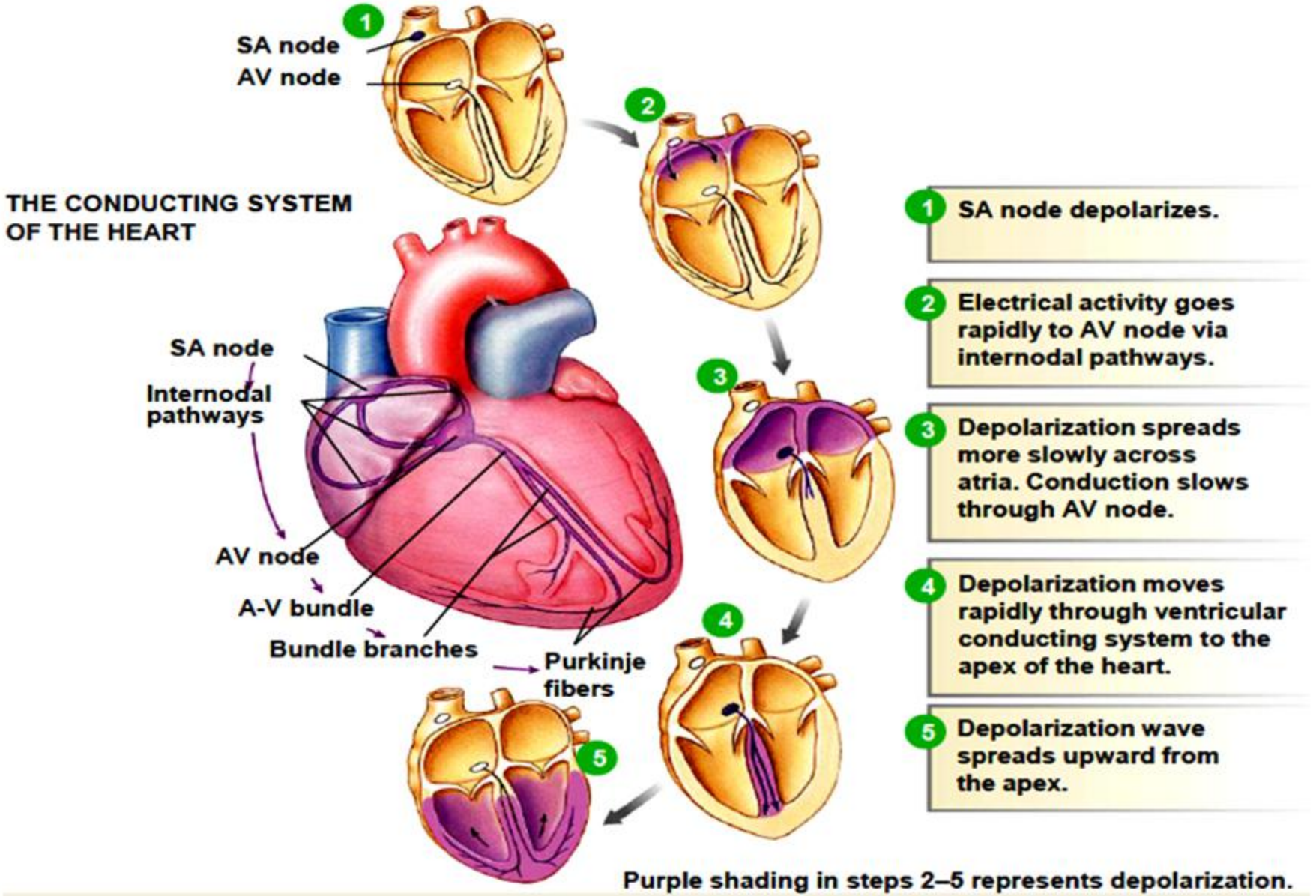


Conduction System of the Heart:
A Conceptual Model for Illustration




Conduction System of the Heart:
A Conceptual Model for Illustration
Inter-nodal Tract
Left Bundle Branch
AV Node
Bundle of HIS
Septal Depolarization Fibers
SA Node
James Fibers
Anterior Superior Fascicle
Posterior Inferior Fascicle
Bundle of Kent
Right Bundle Branch

Electron Conduction in Heart



Introduction to Electrocardiography (ECG & EKG)

- **Electrocardiography**-graphic recording of the electrical activity (potentials) produced by the **conduction system** and the **myocardium** of the heart during its depolarization / re-polarization cycle.
- Each event has a distinctive wave form, the study of which can lead to greater in sight into a patient's cardiac pathophysiology.
- During the late 1800's and early 1900's, **Dutch physiologist Wille Einthoven developed the early electrocardiogram**. He won the ***Nobel prize*** for its invention in 1924.
- **Hubert Mann** first uses the ***electrocardiogram to describe*** electrocardiographic changes associated with a heart attack in 1920.

Principles of Electrocardiography

- As electrical depolarization spreads through a tissue, current flows between adjacent depolarized and polarized regions.
- **This separation of charges across a finite resistance is a dipole, which is detected as a voltage by a voltmeter.**
- ***The ECG machine and chart recorders are sophisticated voltmeters.***
- The dipole can be detected by a pair of electrodes (a "**lead**") connected to the positive and negative poles of a voltmeter.

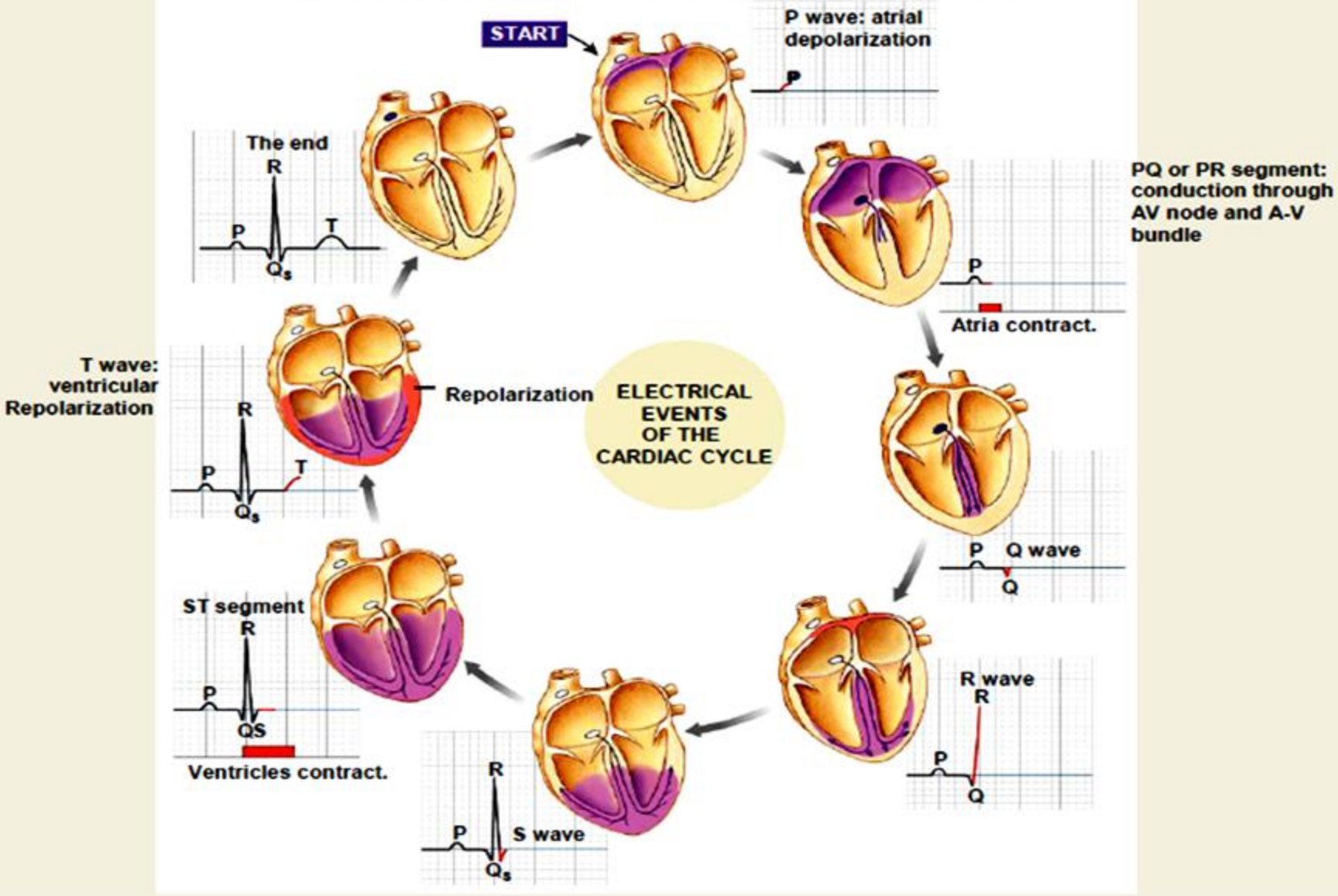
Cardiac muscle contraction is electrical---

- This recording is called an EKG or ECG- **Electrocardiogram** and the machine is called an **Electrocardiograph**

The ECG tells three things:

- **E-e**lectrical conduction problems in the heart
- **C-c**ardiac enlargement
- **G-**cardiac Dama**g**e

Correlation Between An ECG and Electrical Events in the Heart



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What types of pathology can we identify and study from ECGs?

- Arrhythmias
- Myocardial ischemia and infarction
- Pericarditis
- Chamber hypertrophy
- Electrolyte disturbances (i.e. hyperkalemia, hypokalemia)
- Drug toxicity (i.e. digoxin and drugs which prolong the QT interval)

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Abnormalities

Abnormal Waves:

- Larger P = Enlarged atrium
- Enlarged Q = Myocardial infarction (MI= Heart attack),

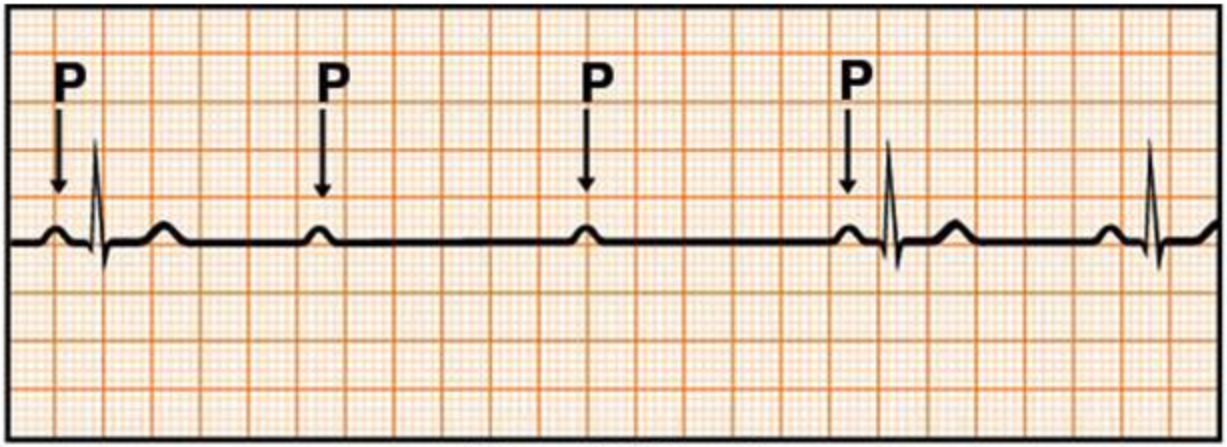
Pathological Q wave

- Enlarged R = Enlarged ventricles
- Flattened T = Coronary artery disease

Abnormal Interval/ Segment:

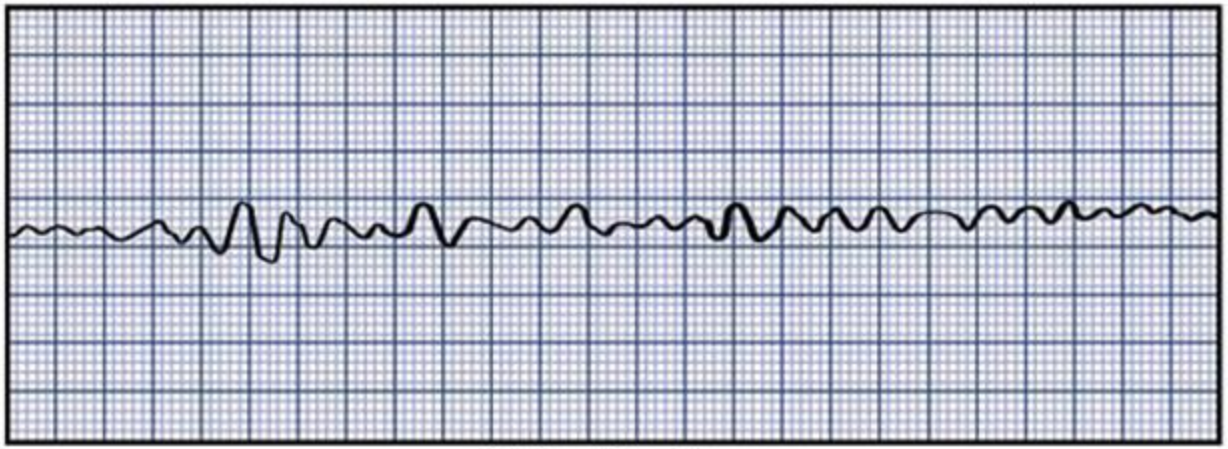
- P-Q interval lengthened = Coronary artery disease, rheumatic fever
- S-T segment elevated = Acute MI, Hyperkalemia.
- S-T segment depressed (below baseline) = Anoxia of heart muscle.
- Q-T interval lengthened (Q-T prolongation) = Myocardial damage, HEART ATTACK, coronary ischemia or conduction anomalies.

ECGs, Abnormal



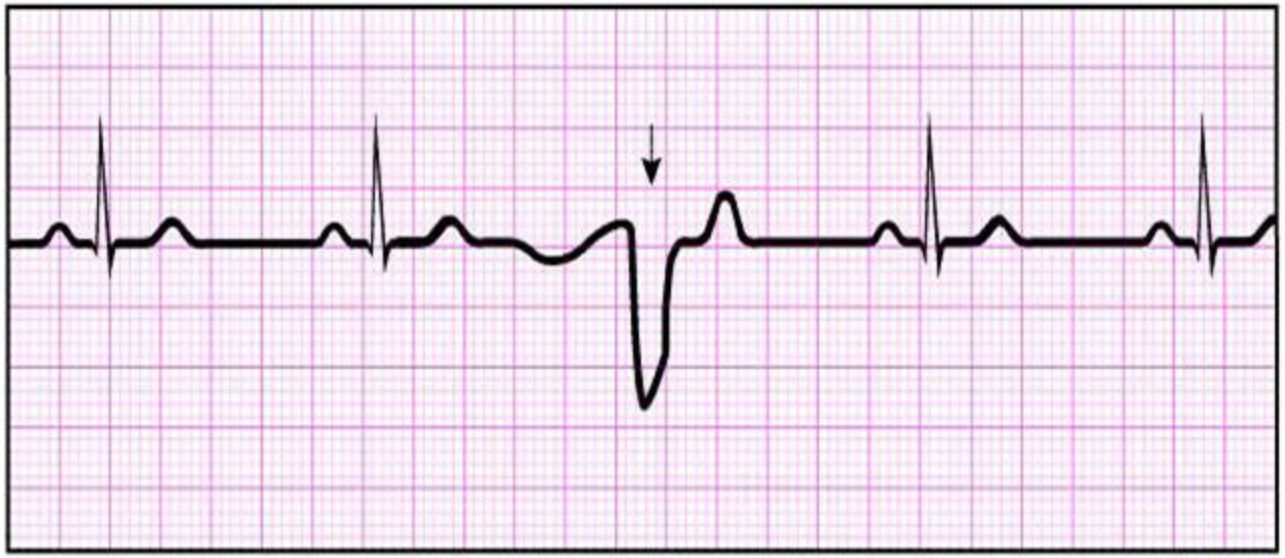
Heart block

Arrhythmia: conduction failure at AV node



Fibrillation

No pumping action occurs



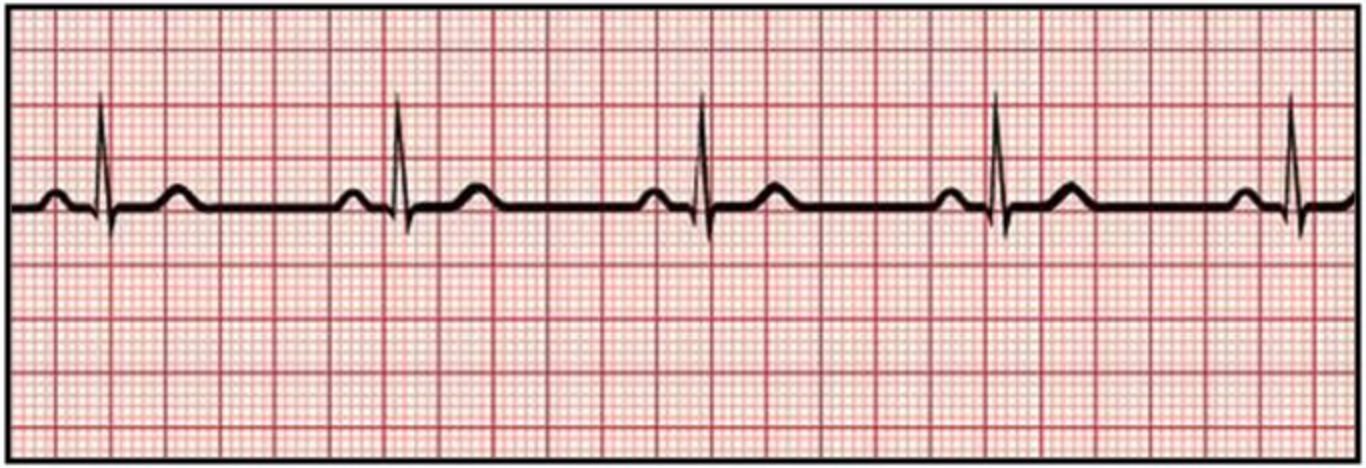
Premature ventricular contraction

- **Extra systole :**

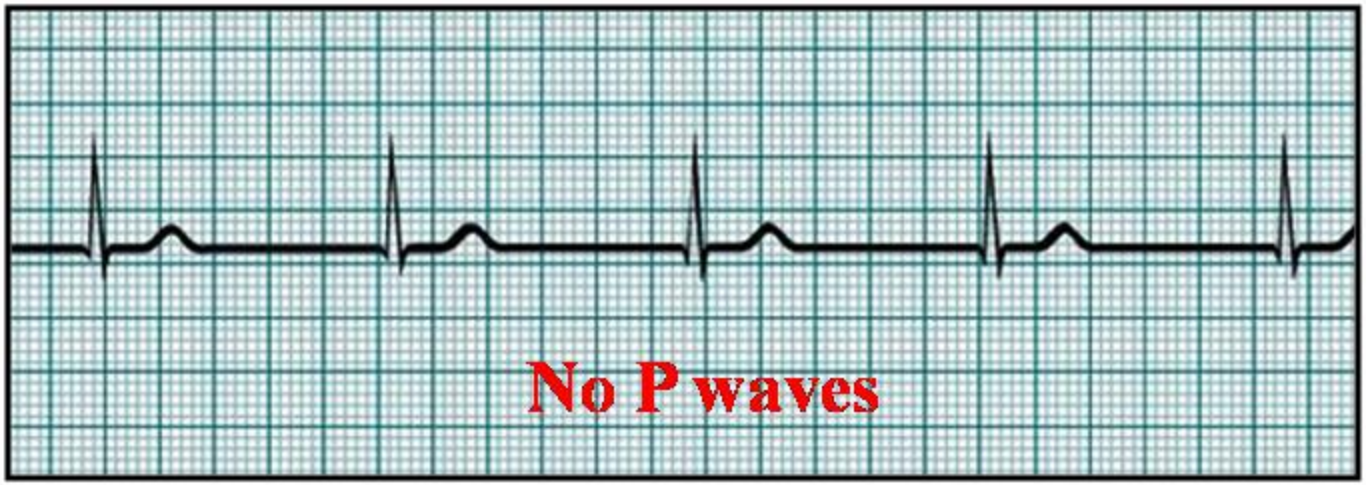
  note the **Inverted QRS complex**,

  Misshapen QRS and T and

  Absence of a P wave preceding this contraction.



Sinus Rhythm (Normal)



Nodal Rhythm (No SA node activity)

Thank you