CVS
Electrical Activity and the Electrocardiogram

F Bukachi

MBChB, MMed, MSc, DIC, PhD

Department of Medical Physiology, University of Nairobi, Kenya

Objectives

- To understand :

- the origin and spread of cardiac excitation

- the recording of a normal electrocardiogram

- Review sample questions

Introduction

- Anatomic considerations (see figure)
  - SA node – located at the junction of at the junction of the superior vena cava and the right atrium
  - AV node – located in the right posterior portion of he interatrial septum
  - SA node and AV node connected by 3 Purkinje like fibres

    (a) anterior internodal tract of Bachman, (b) middle internodal tract of Wenckebach, and (c) posterior internodal tract of Thorel
- Conduction occurs via atrial myocyte but is fastest in the bundles.
- AV node only conducting pathway between atria and ventricles
- SA node and AV node contain P-cells - histology
- Nerve supply and relationship to embryonic development

The conducting system of the Heart

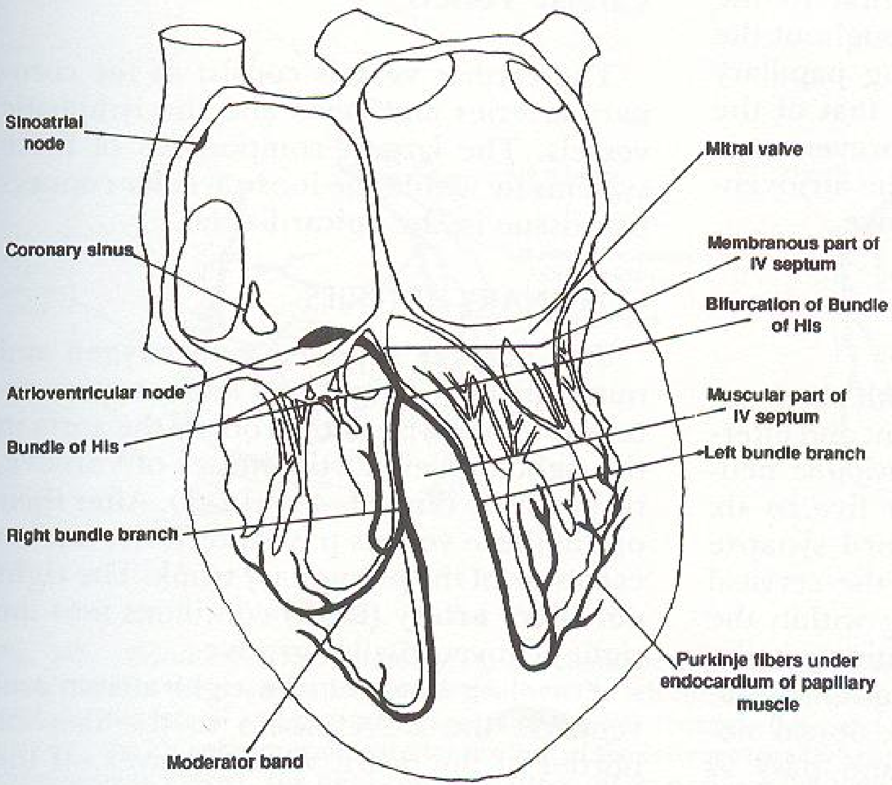
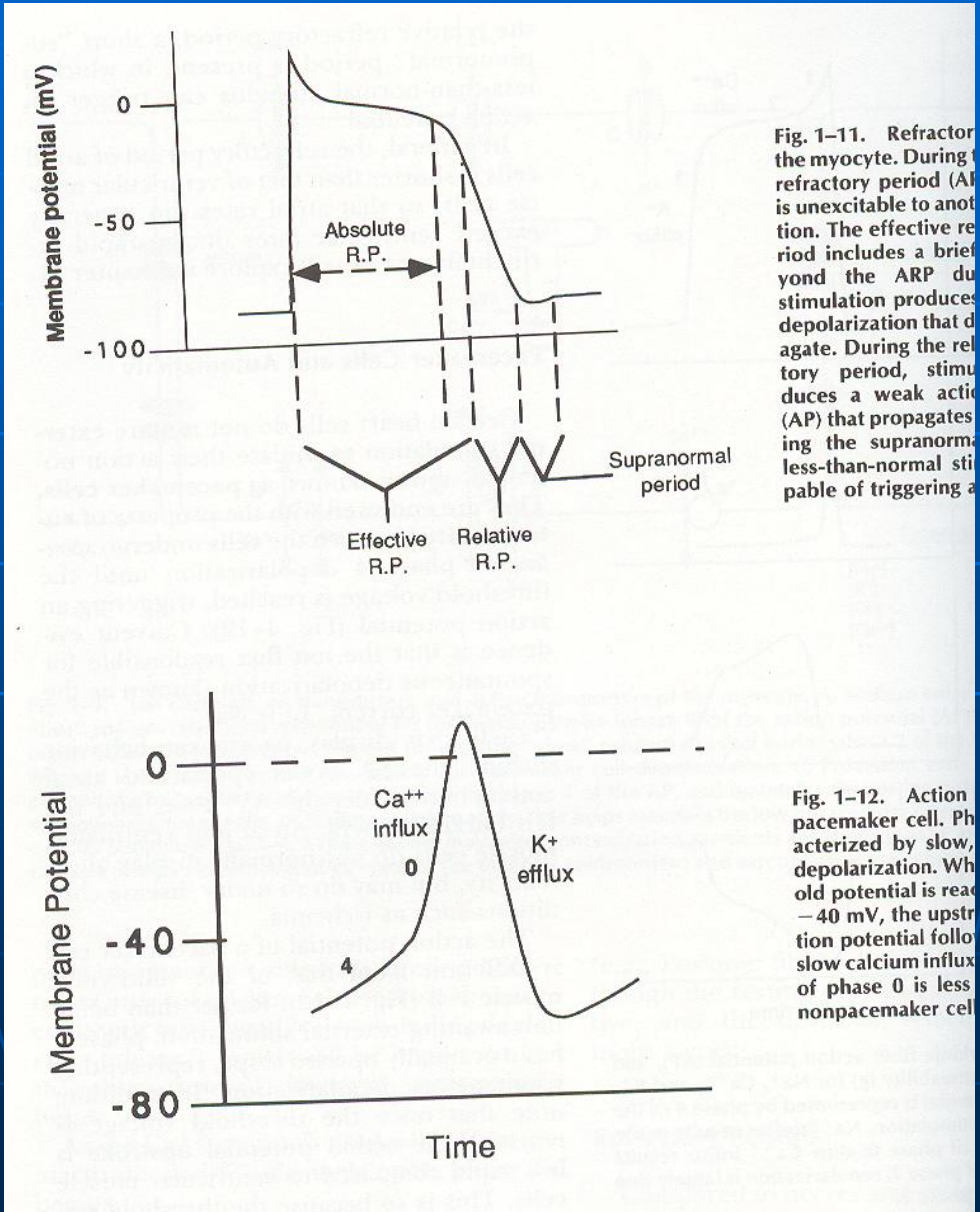


Fig. 1–3. Main components of the cardiac conduction system include the sinoatrial node, atrioventricular node, bundle of His, right and left bundle branches, and the Purkinje fibers. The moderator band carries a large portion of the right bundle.

Pacemaker cells and automaticity

- Pacemaker cells – do not require external stimulation to initiate an Action potential
- They have the property of automaticity – undergo spontaneous phase 4 depolarization – Na^+ responsible
- Pacemaker behaviour – cells of SAN, AVN, HIS purkinje fibres, (Ventricular muscle under disease conditions!)
- Action Potential of Pacemaker cell – different from Ventricular muscle cell (see figure)

AP –Ventricular myocyte vs Pacemaker cells



Spread of Cardiac Excitation

- SA node initiates excitation (rate 60-80 beats/min)

- Spreads to AV Node – delay of approx 0.1 sec (reasons?)
  - ✓ small diameter fibres
  - ✓ Pause allows atria to fully empty their contents
  - ✓ Allows AV-node to serve as a 'gatekeeper' of onward conduction
  - ✓ Role of Autonomic nervous system (explain?)

- Depolarization spreads rapidly from top of the Septum to all parts of the ventricle in 0.08-0.1 sec
- Normal sequence of cardiac depolarization (see figure)

The conducting system of the heart

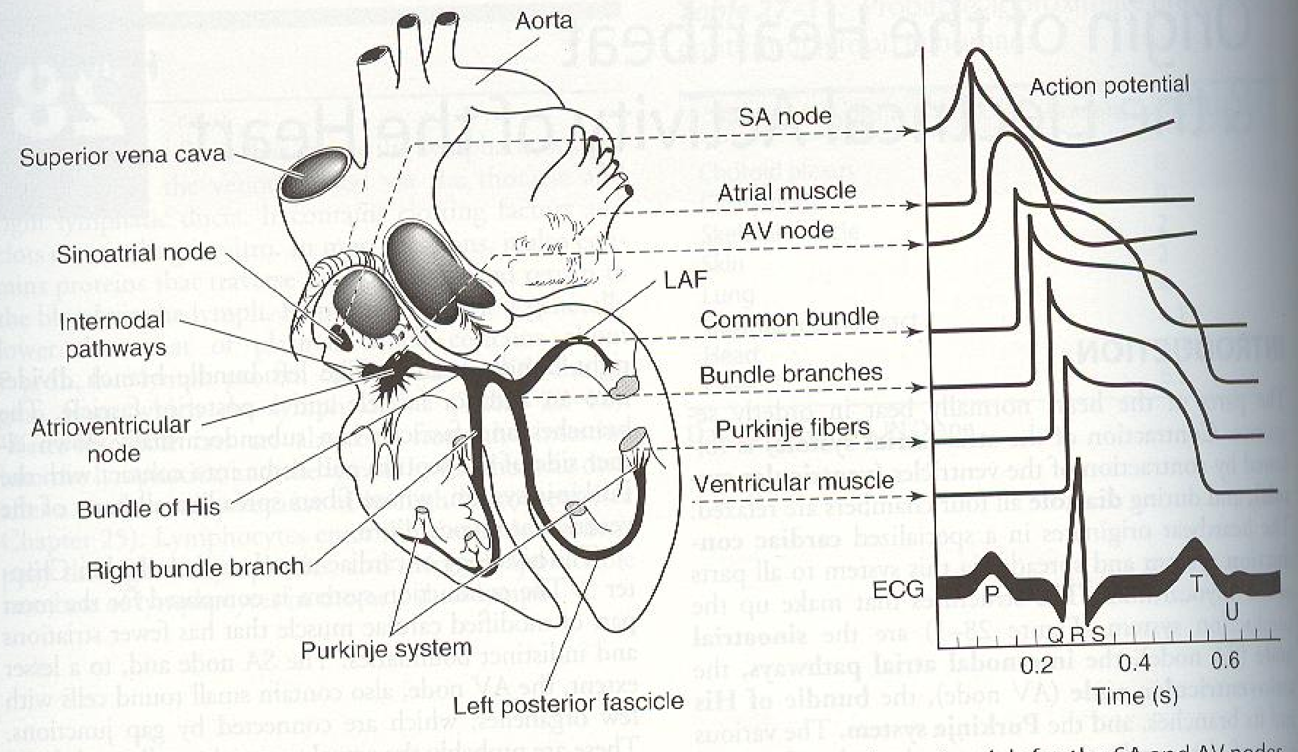
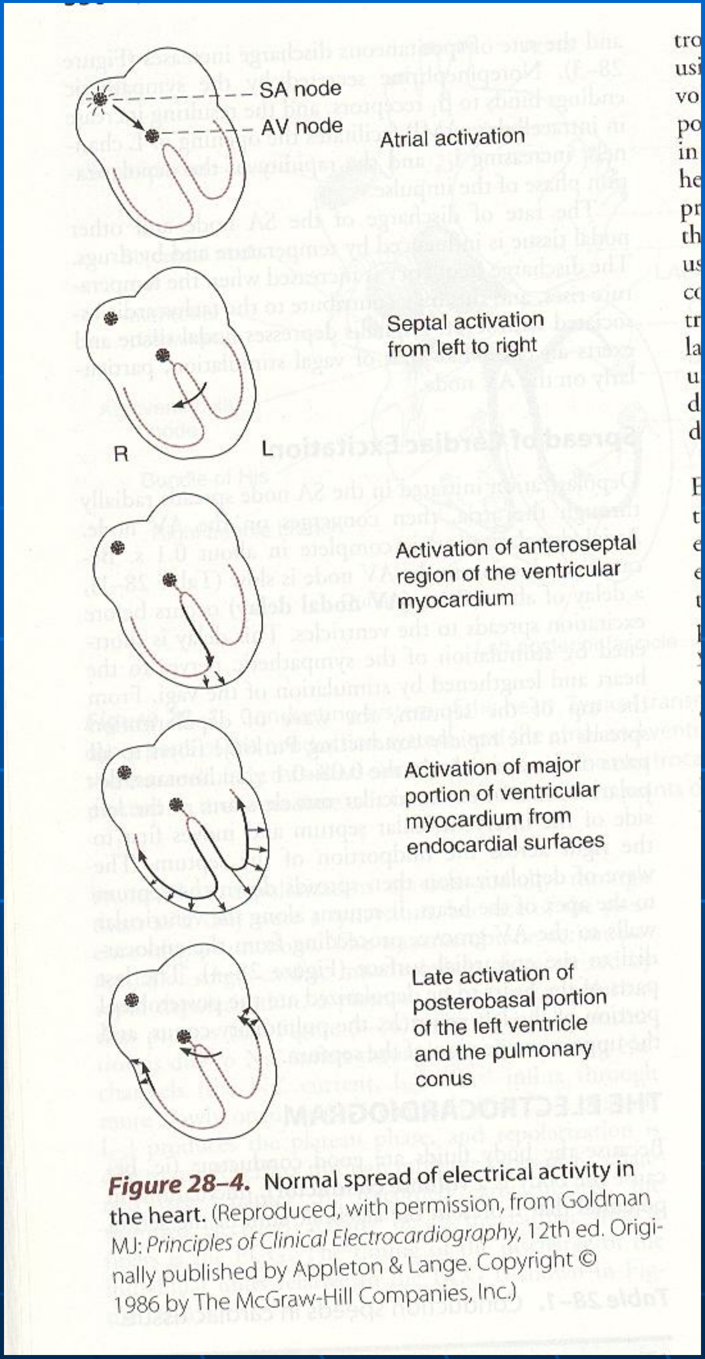


Figure 28–1. Conducting system of the heart. Typical transmembrane action potentials for the SA and AV nodes, other parts of the conduction system, and the atrial and ventricular muscles are shown along with the correlation to the extracellularly recorded electrical activity, ie, the electrocardiogram (ECG). The action potentials and ECG are plotted on the same time axis but with different zero points on the vertical scale. LAF, left anterior fascicle.



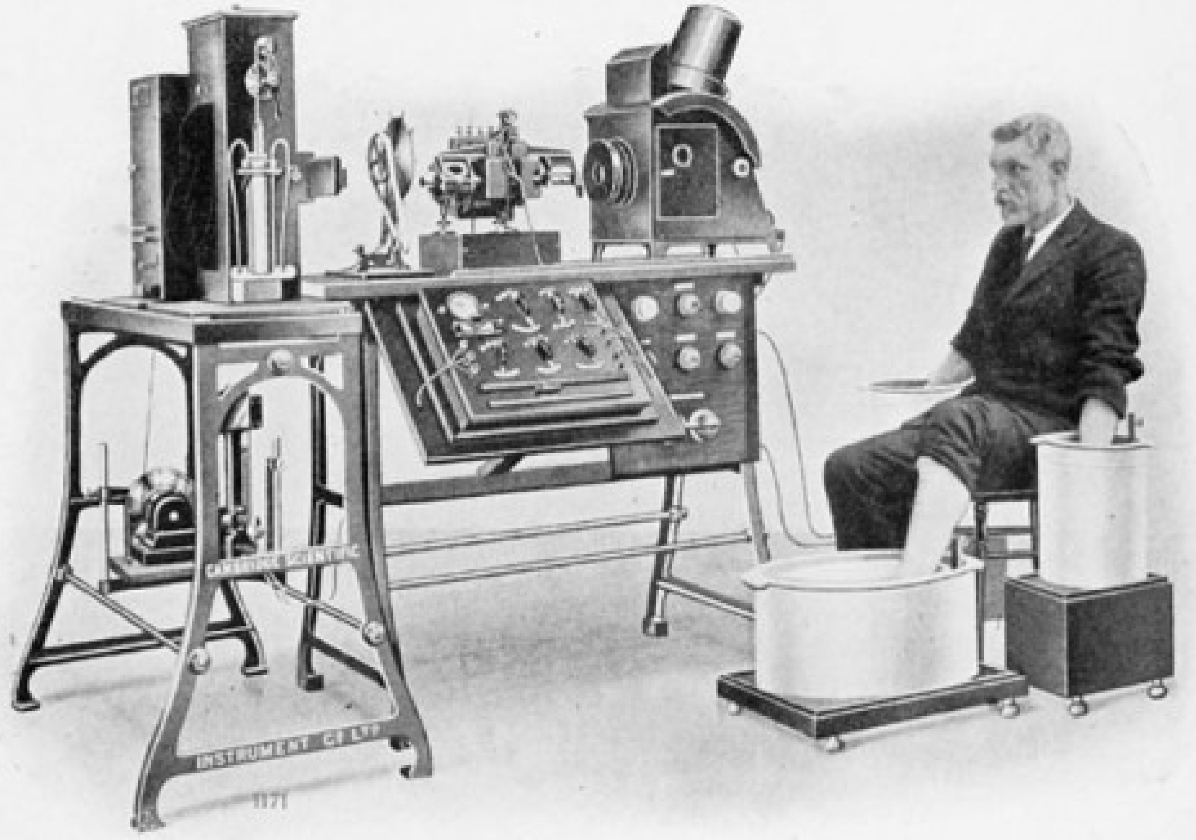
Normal sequence of cardiac depolarization

ECG: What is it?

- Surface recording of the algebraic sum of the action potentials of cardiac fibres
- Human body is a volume conductor
- Action potentials fluctuate and are recorded by an Electrocardiograph machine on moving paper strip

Willem Einthoven

Nobel prize in 1924 for electrocardiogram
(discovered in 1903)



PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSED IN JARS OF SALT SOLUTION

ECG: The Lead Reference system I

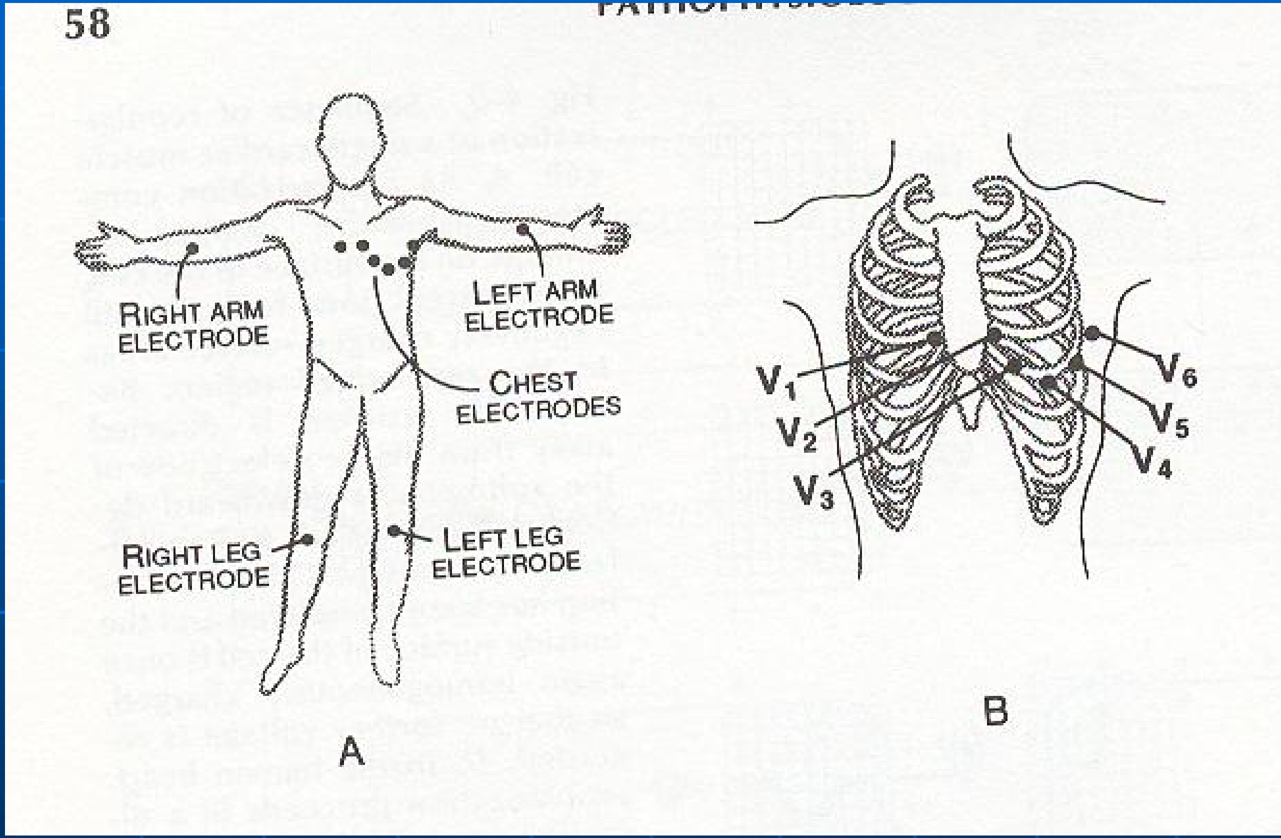


Fig. 4–3. *A*, Standard positions of the EKG electrodes. *B*, Close-up view of chest electrode placement.

ECG: The Lead Reference system II

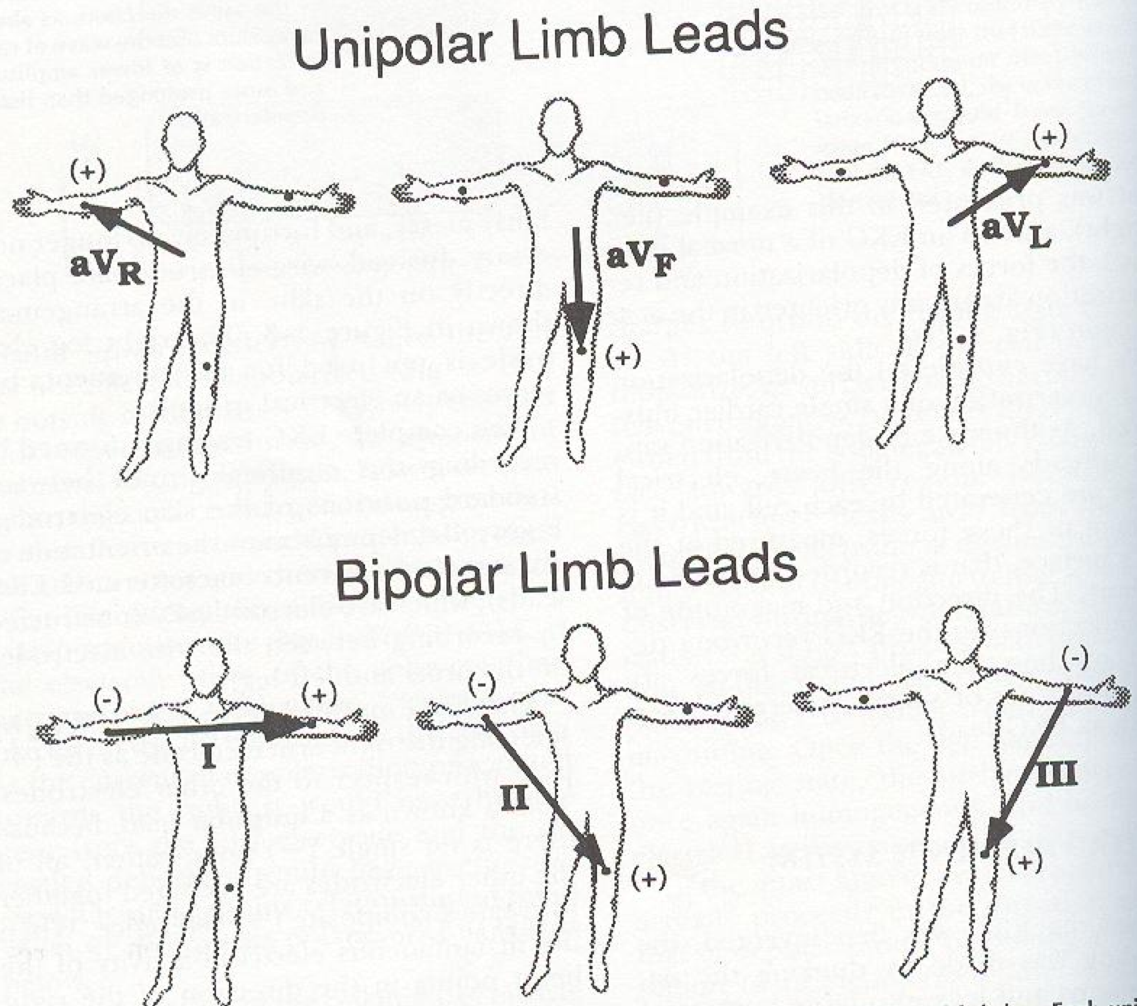
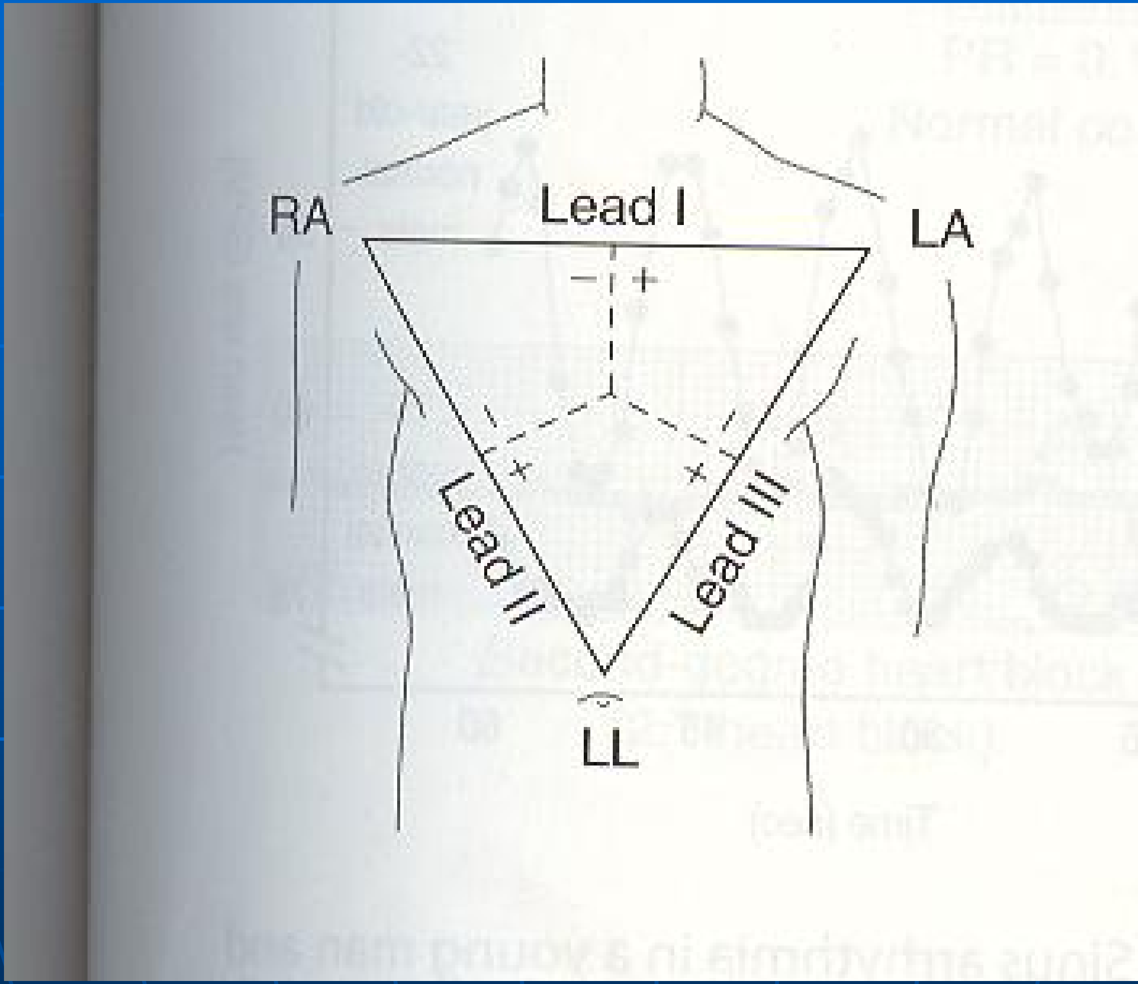
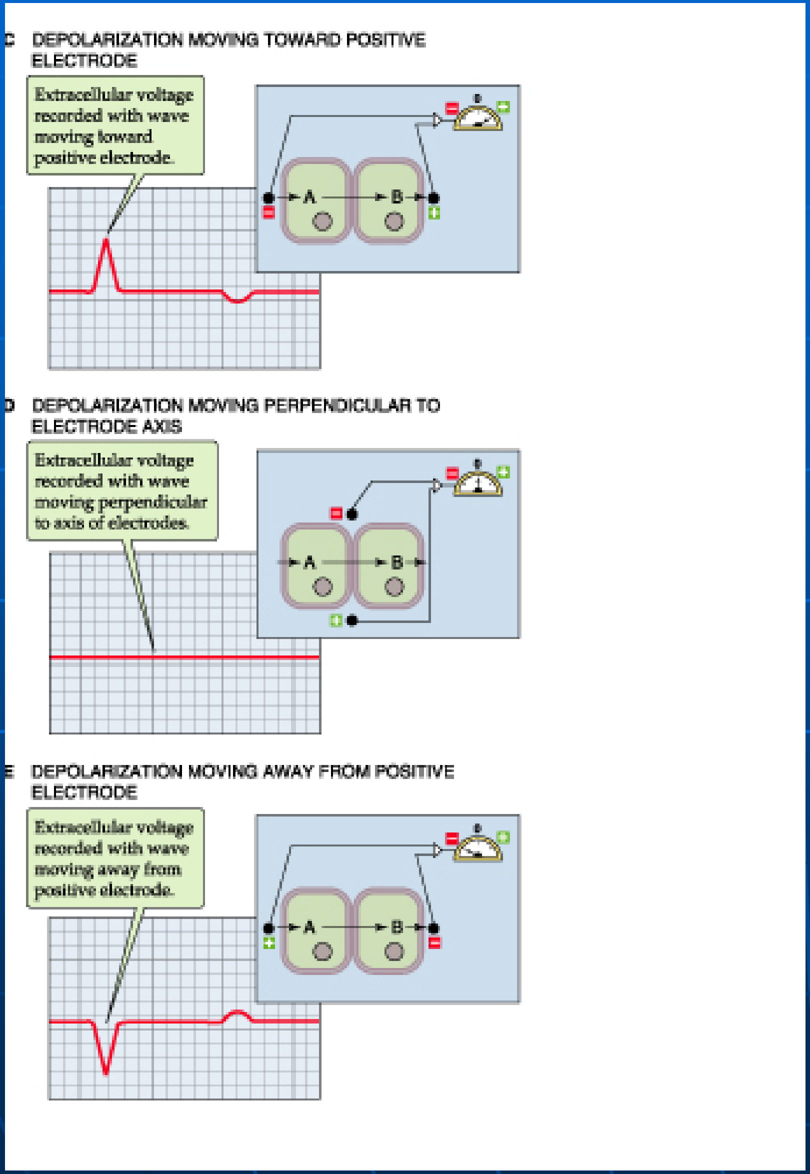


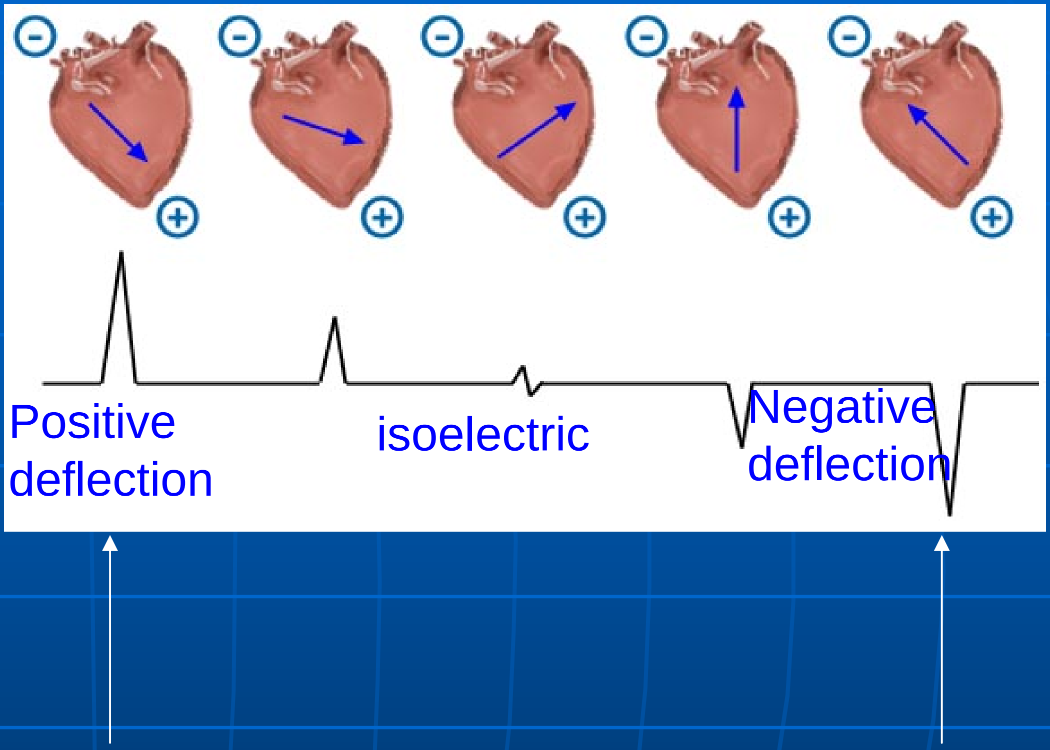
Fig. 4–4. The six limb leads are formed from the electrodes placed on the arms and left leg. Each unip lead has a (+) designated electrode (for the unipolar leads, the (−) pole is an average of the other electrod Each bipolar lead has specific (−) and (+) designated electrodes.

Einthoven's Triangle



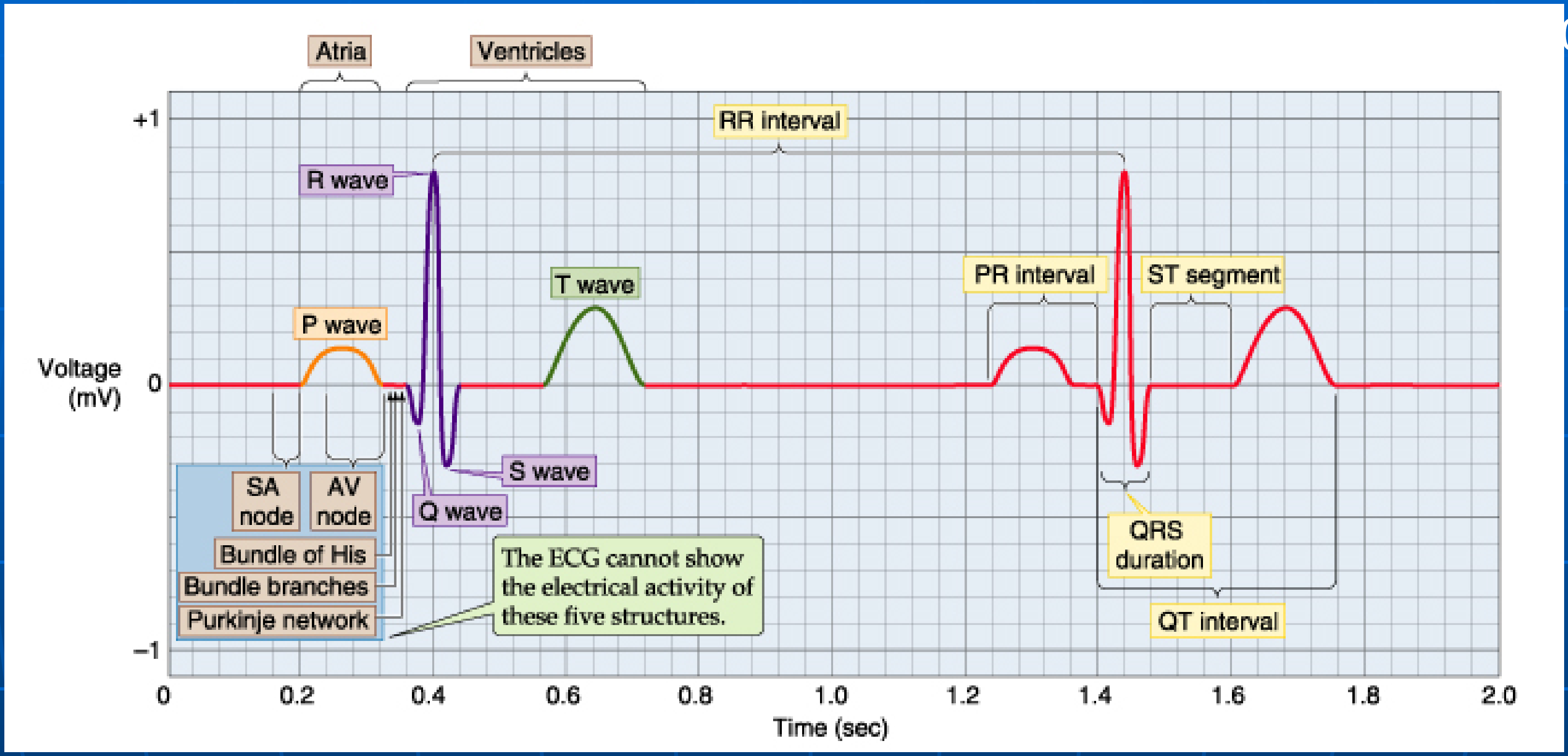
ECG activity: Two cell model





When wave of depolarization moves towards a positive electrode, the deflection is ***positive.***

The Normal Electrocardiogram



0-6

P wave – depolarization of atria

QRS complex – depolarization of ventricular muscle

T wave – repolarization of ventricular muscle

*repolarization of atria lies under QRS

ECG: Interpretation

- Sequence of analysis

1. Heart Rhythm
2. Heart Rate
3. Intervals (PR, QRS, ST)
4. Abnormalities of the P wave
5. Abnormalities of the QRS
6. ST and T wave abnormalities

Normal ECG: Intervals and segments

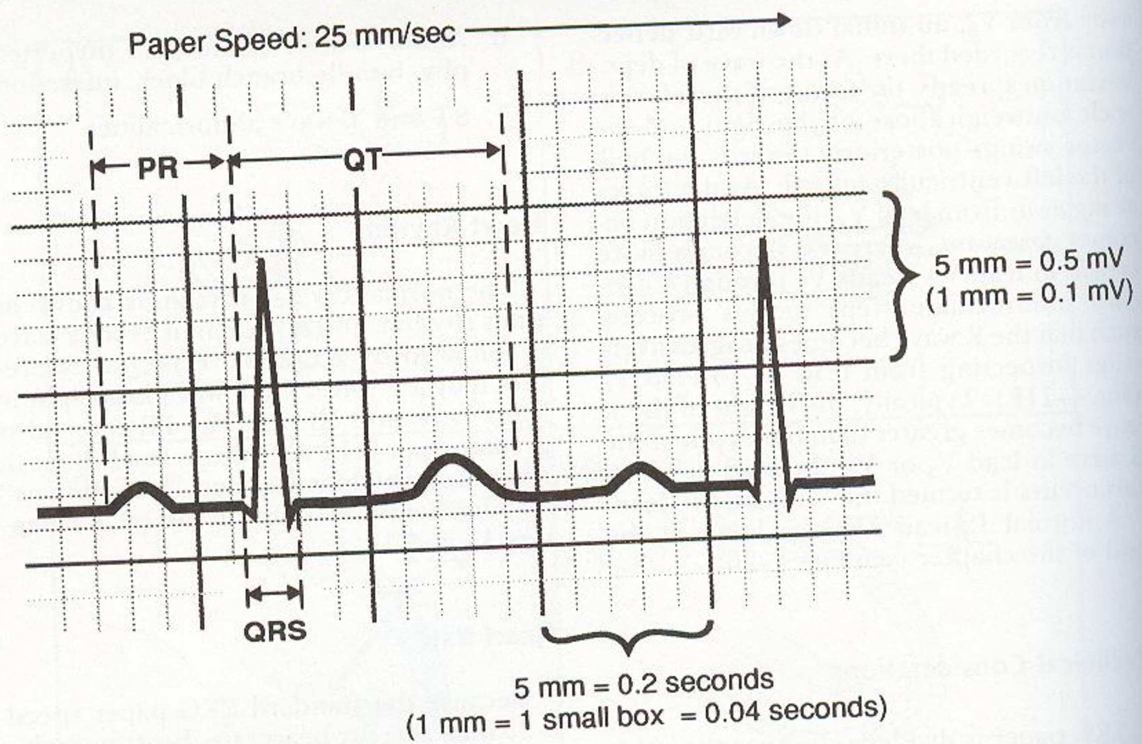


Fig. 4–12. Enlarged view of an EKG strip. The paper travels through the machine at 25 mm/sec, so that each 1 mm on the horizontal axis represents 0.04 sec. Each 1 mm on the vertical axis represents 0.1 millivolt. Interval measurements are: PR (from the beginning of the P wave to the beginning of the QRS) = 4 small boxes = 0.16 sec; QRS duration (from the beginning to the end of the QRS complex) = 1.75 small boxes = 0.07 sec; QT interval (from the beginning of the QRS to the end of the T waves) = 8 small boxes = 0.32 sec. The corrected $QT = \frac{QT}{\sqrt{R-R}}$. Because the R−R = 15 small boxes (0.6 sec), the corrected $QT = \frac{0.32}{\sqrt{0.6}} = 0.41$ sec.

Homework! – check up the normal values of ALL Intervals and Segments

CVS
The Heart Mechanical Activity

Anatomic considerations

- Heart built on a fibrotendinous ring – Annulus fibrosus – located at the atrioventicular junction
- Muscular atria and ventricles are attached to either side of the ring
- Ring perforated by 4 apertures each containing a valve (see figure)
- Fibrotendinous ring insulates the ventricles electrically from the atria

The Heart: Fibrotendinous Ring

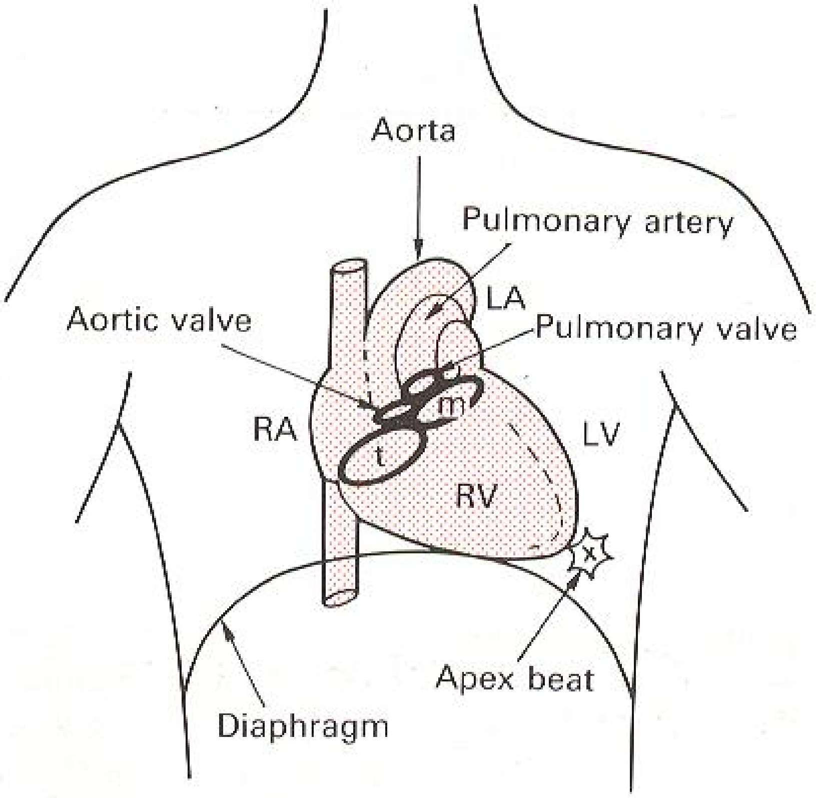


Figure 2.1 The heart lies obliquely across the chest. The fibrotendinous ring (black) acts as a base for the heart. It contains the tricuspid (t), mitral (m), aortic and pulmonary valves grouped in an oblique plane beneath the sternum. The apex of the heart is formed by the left ventricle (LV), and the anterior surface is formed by the right ventricle (RV) and right atrium (RA). The inferior surface of the heart and the pericardium (not shown) rest on the central tendon of the diaphragm

Mechanical events of the Cardiac cycle

- Atria and ventricles contract in sequence resulting in a cycle of pressure and volume
- Cardiac cycle has 4 phases (arbitrary)
- (i) ventricular filling
- (ii) Isovolumetric contraction
- (iii) Ejection
- (iv) Isovolumetric relaxation
- Figure based on human cycle – 0.9 sec duration, (67 beats/min)

Cardiac cycle: valve and volume changes

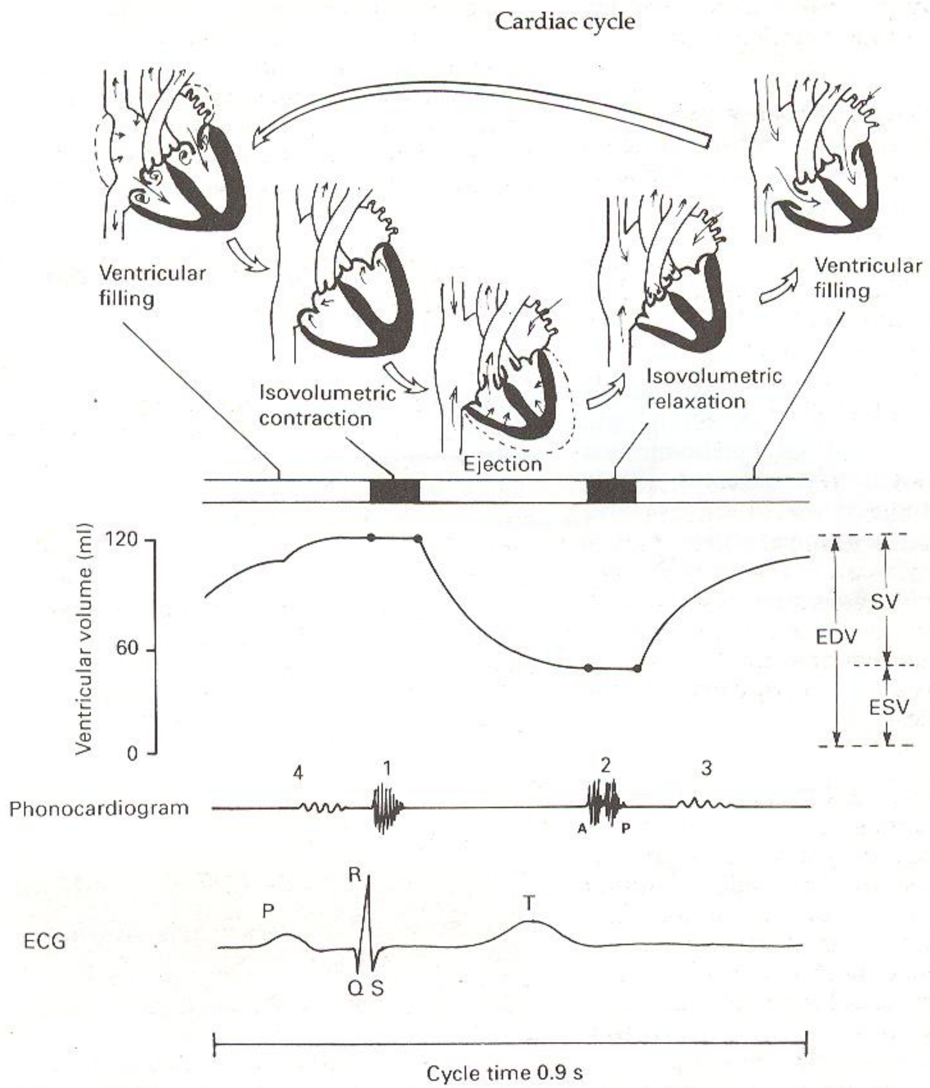
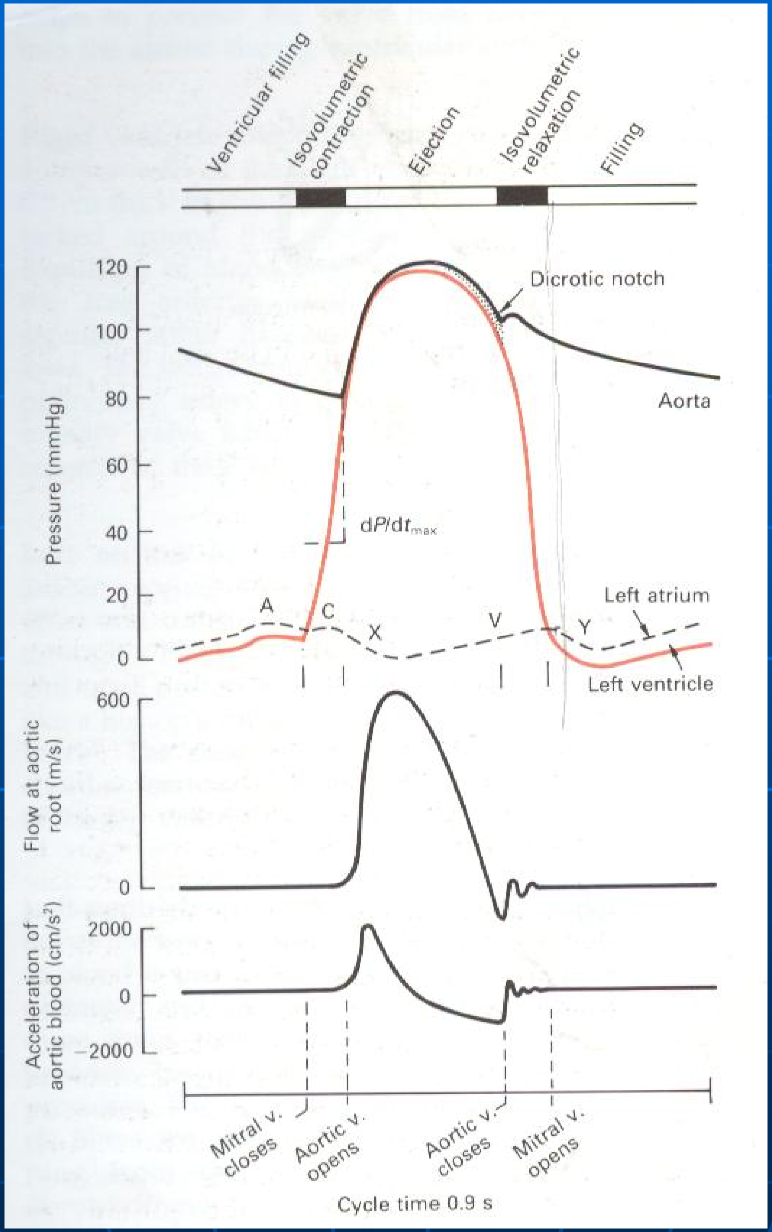


Figure 2.3 The changes in valve setting and ventricular volume during one cardiac cycle lasting 0.9 s. EDV, end-diastolic volume; ESV, end-systolic volume; SV, stroke volume. The ejection fraction is SV/EDV. The heart sounds on the phonocardiogram are numbered 1 to 4 and the second sound is split here into an aortic component (A) and pulmonary component (P). The electrocardiogram (ECG) waves are described in the text

Pressure and outflow: left ventricle



Ventricular filling (Diastole)

- Duration 0.5 sec
- Inlet valves (tricuspid and mitral): open
- Outlet valves (pulmonary and aortic): closed
- Lasts about two-thirds of cardiac cycle
- Rapid filling –coincides with atrial diastole – lasts 0.15 sec
- Atrial systole – boosts filling by 15-20%
- End-diastolic volume: volume of blood in the ventricle at the end of filling ≈ 120 mls
- Corresponding pressure is End-diastolic pressure – just a few mm Hg

Isovolumetric contraction

- Duration: 0.05 sec
- Inlet valves: closed
- Outlet valves: closed
- Ventricle is a closed chamber
- Pressure rises steeply

Ejection

- Duration: 0.3 sec
- Inlet valves: closed
- Outlet valves: open
- Outflow valves open when ventricular pressure exceeds arterial pressure
- ¾ of Stroke volume is ejected in the first phase of ejection – rapid phase – 0.15 sec
- Ventricle empties just about two-thirds – average ejection fraction is approx 0.67 – stroke volume of about 70-80 ml

Isovolumetric relaxation

- Duration: 0.08 sec
- Inlet valves: closed
- Outlet valves: closed
- Ventricle – closed chamber
- Ventricular pressure falls very rapidly
- A-V valves open when ventricular pressure falls below atrial pressure

The ventricular pressure-volume loop

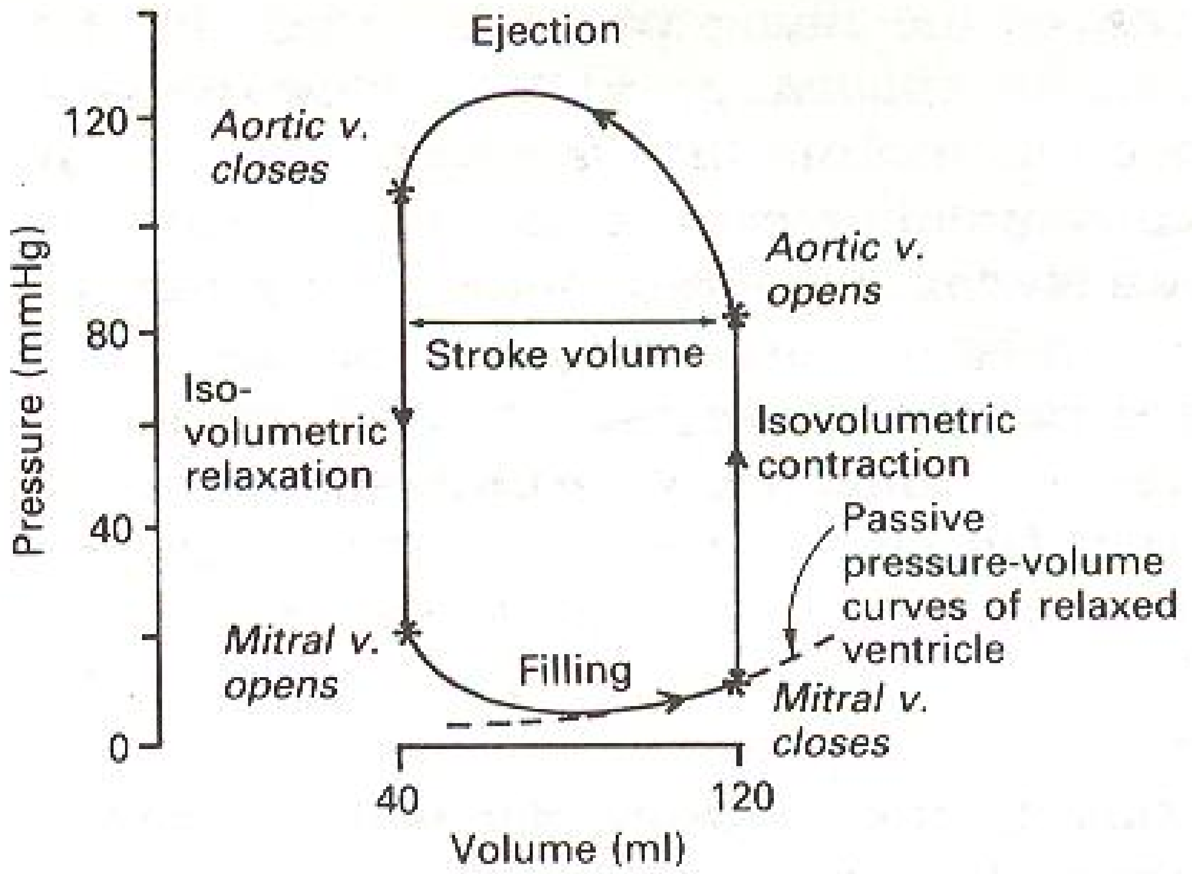


Figure 2.5 Pressure–volume cycle of human left ventricle

Heart Sounds

- Two sounds typically heard through a stethoscope – "lub" first heart sound and "dup" second sound.
- First : caused by vibrations from sudden closure of the mitral and tricuspid valves
- Second: vibrations associated with closure of aortic and pulmonary valves
- Third: heard in many normal young persons – one third into diastole –rapid ventricular filling phase
- Fourth: heard just before first sound – when atrial pressure is high or ventricular hypertrophy –rarely heard in normal adults

Effect of heart rate on phase duration

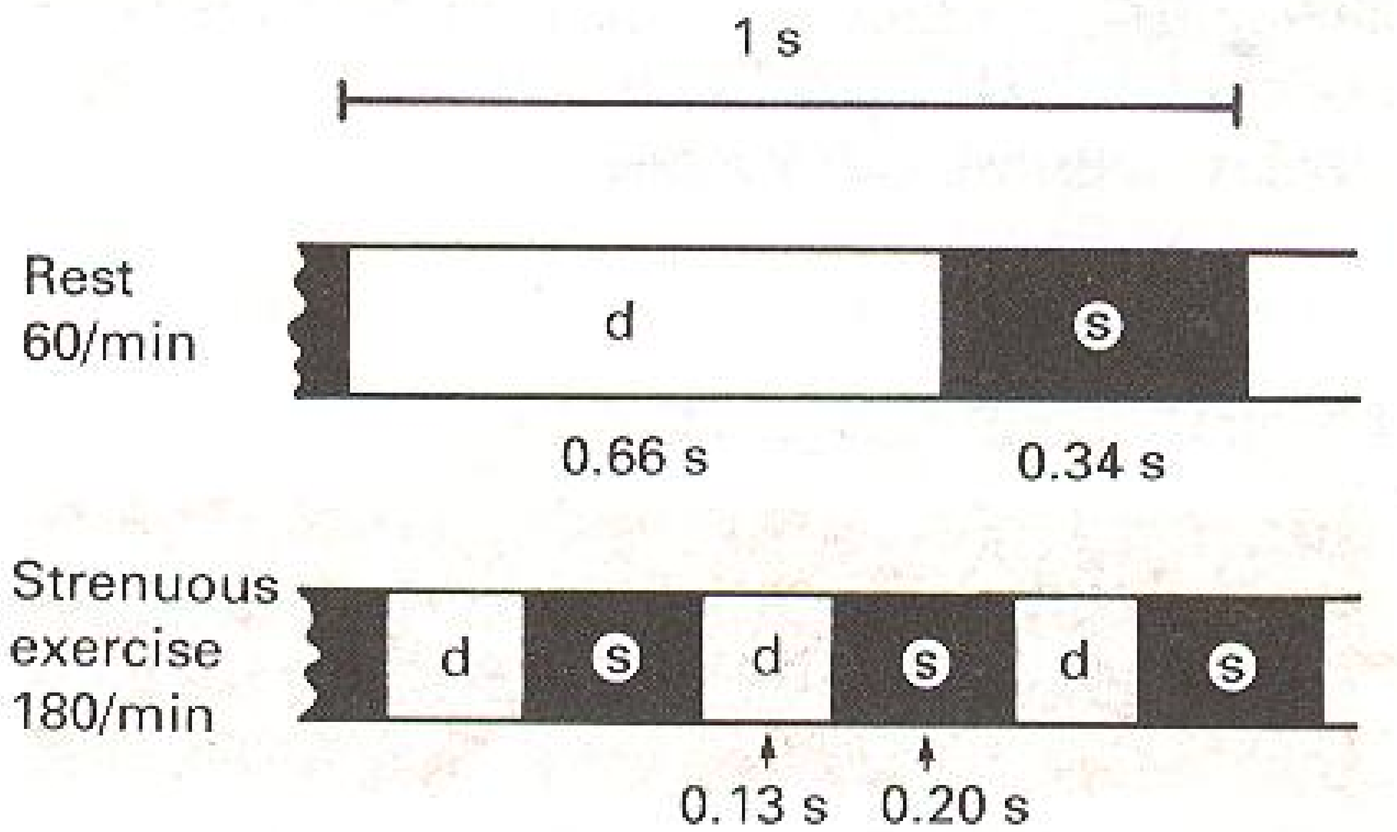


Figure 2.6 Effect of heart rate on the diastolic period available for filling. d, diastole; s, systole. Diastole is curtailed more than systole as heart rate increases

Homework

- Read about:
- Arterial pressure
- Atrial pressure changes
- The Jugular Pulse

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Intervals and Segments

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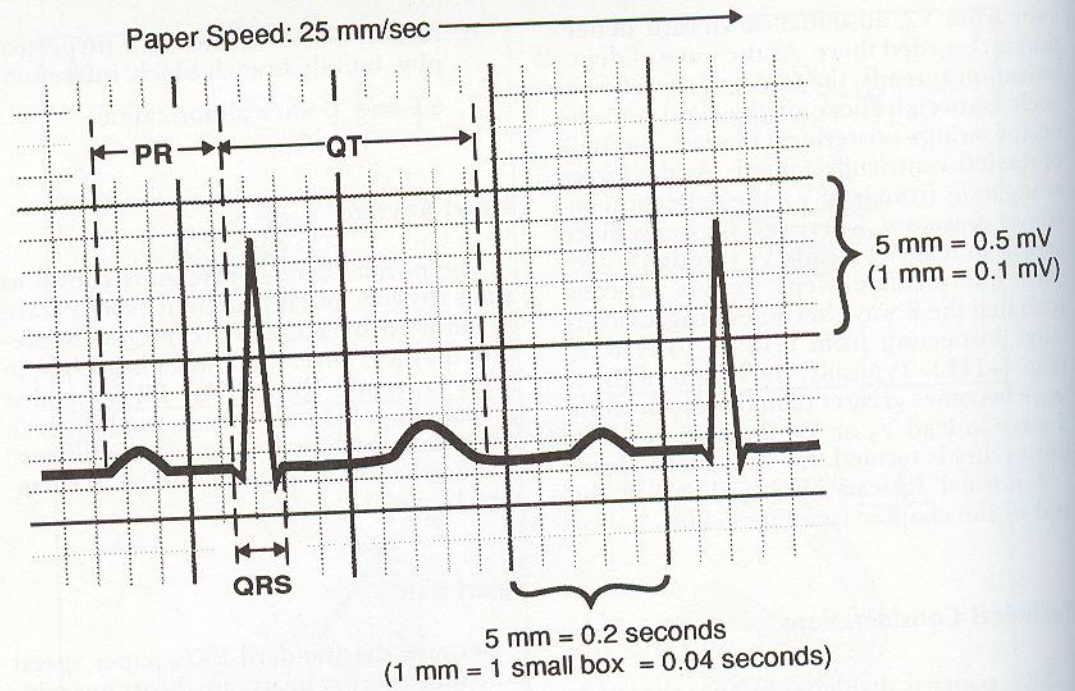

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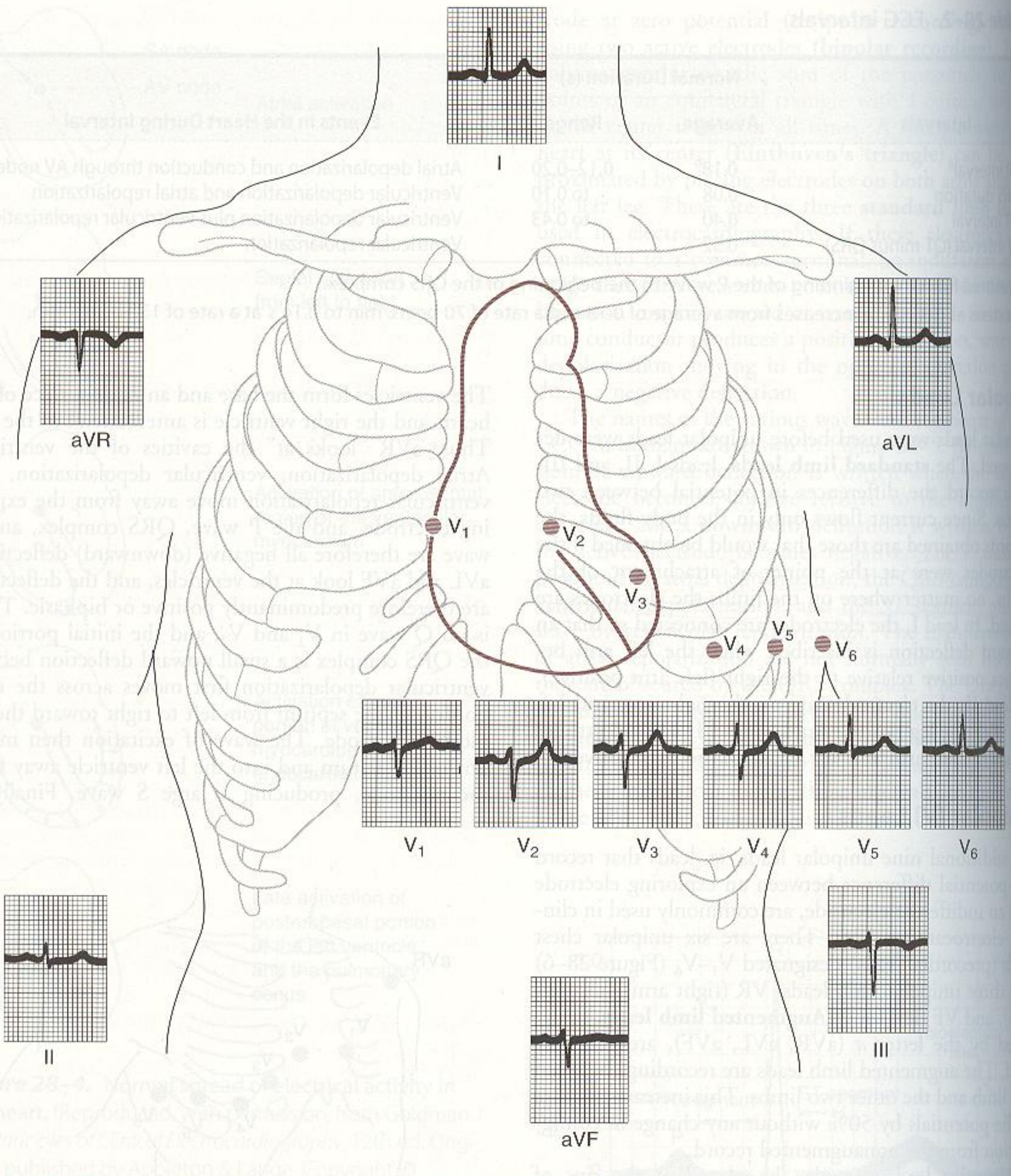

Figure 28–7. Normal ECG. (Reproduced, with permission, from Goldman MJ: *Principles of Clinical Electrocardiography,* 12th ed. Originally published by Appleton & Lange. Copyright © 1986 by The McGraw-Hill Companies, Inc.)