THE UNIVERSITY OF MELBOURNE

Melbourne Veterinary School

Lecture 5, Week One
Observing the Electrical Activity of the Heart-

Semester Two 2023

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VETS30014 / VETS90124

Check points for Learning: Lecture Four

1. The rise in intra-cellular calcium that initiates contraction results from
   _____________,& _____________
2. The degree of tension generated in a cardiac myocyte during contraction depends on ____ .
3. Calcium enters the cell through ____ channels in the sarcolemma/ T tubules.
4. During relaxation calcium is removed from the cytosol by ________ & ________ .
5. The Frank- Starling law of the heart states that ______________ .
   Why is this significant?
6. An inotrope is an agent that _______ .
   An example of a physiological inotrope is ________ .

Measuring the Electrical Activity of the Heart

- What does an ECG measure
- How is an ECG possible?
  - Einthoven's hypothesis
- How good was Einthoven?
  - or does the hypothesis stand up?
- Making sense of a trace
  - P, QRS and T
- Normal and abnormal rhythms

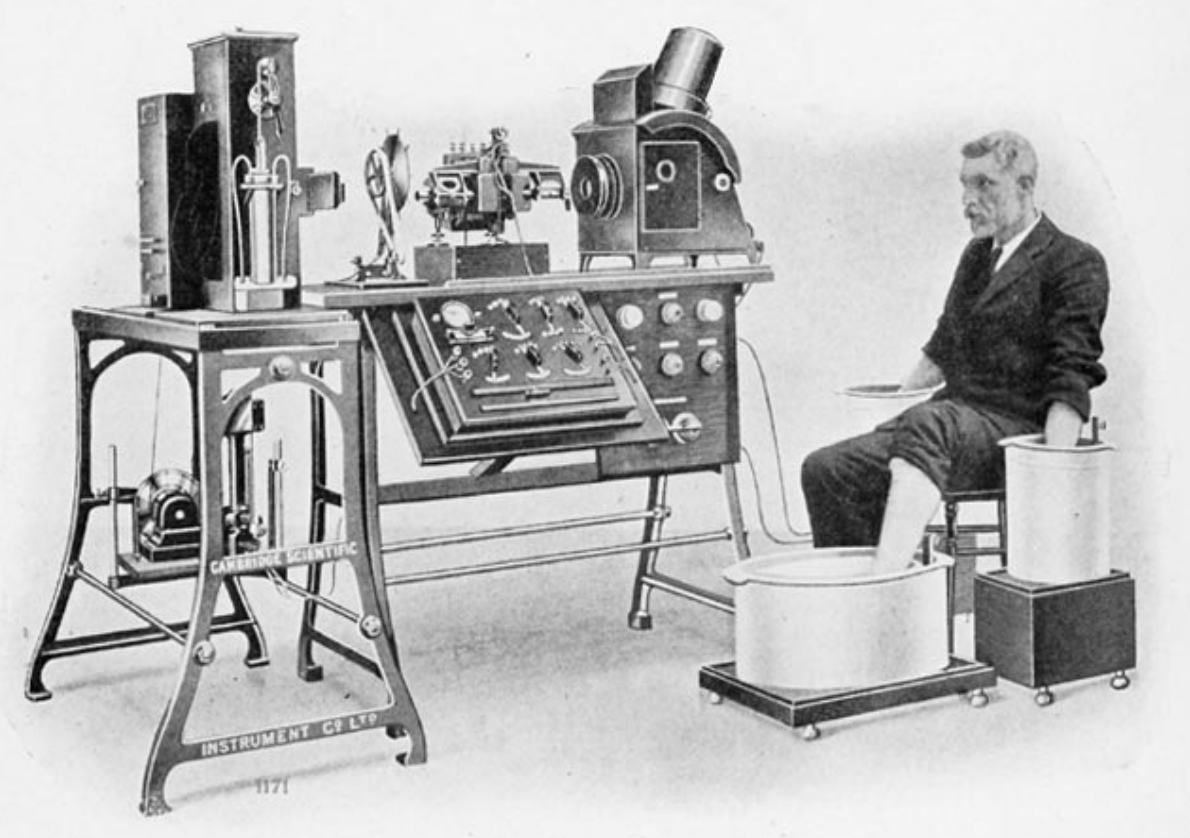
ECG

Electro → *Electrical*

Cardio → *Heart*

Gram → *Recording*

Uses a VoltMeter to record electrical activity in the heart over time



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

The basis of the electrocardiogram

- The body acts as a volume conductor
- When cardiac muscle depolarises, extracellular currents between depolarised and resting cells cause potential differences that can be measured at the body surface

The basis of the electrocardiogram

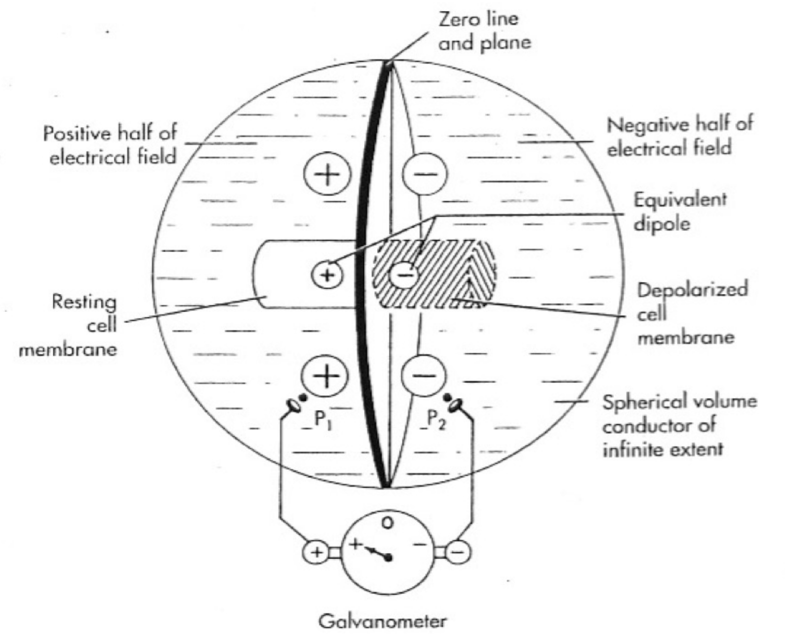


FIGURE 5-7 Schematic representation of equivalent dipoles along the surface of a wavefront. Two electrodes (+ and −) have been placed on either side of the wavefront and attached to a galvanometer to form a lead and record the electric field. The wavefront is spreading from ~~left to right~~, toward the positive pole, resulting in a positive deflection on the galvanometer. (From Cooksey JD, Dunn M, Massie E: *Clinical vectorcardiography and electrocardiography,* Chicago, 1977, Mosby.)

Right to left towards the positive pole

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The basis of the electrocardiogram

- The wave front of depolarisation can be thought of as a series of electrical dipoles (regions of charge separation).
- Each individual dipole is orientated in the direction of local wavefront movement.

The basis of the electrocardiogram

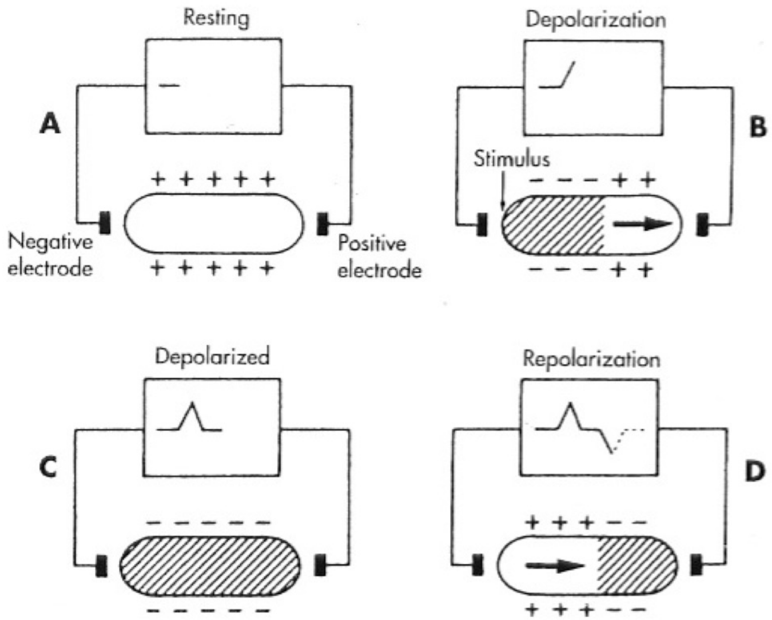

FIGURE 5-8 Similar drawing to Figure 5-7, in which a positive and a negative electrode have been placed on either side of a strip of myocardium. The left end is activated and the wave of depolarization spreads from left to right, toward the positive electrode. This produces a positive (upright by convention) deflection on the recording paper of the electrocardiograph. When fully depolarized the deflection returns to baseline. Repolarization results in the opposite. (From Tilley LP: Essentials of Canine and Feline Electrocardiography, ed 3, Philadelphia, 1992, Lea & Febiger.)

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The basis of the electrocardiogram

- The net dipole movement at any instant in time points in the general direction of wavefront movement at that instant.
- The magnitude of the dipole depends on
  - how many cells are depolarising at that instant
  - vector analysis of simultaneous dipoles

Einthoven's hypothesis underpins interpretation of an electrocardiograph trace

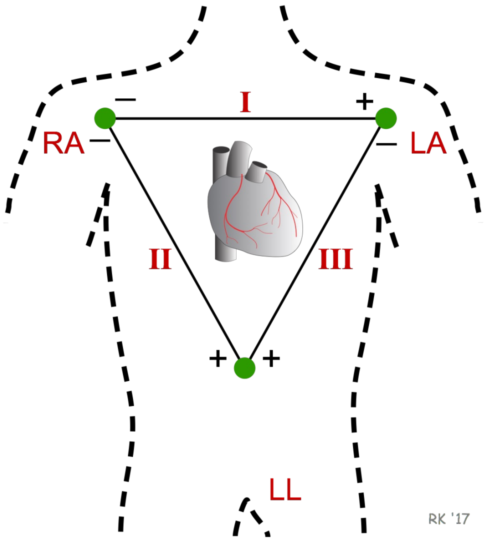
Einthoven's hypothesis

- electrical forces of the heart originate in a small area at the centre of a homogenous volume conductor
- The attachments of the arms and legs to the trunk are points equidistant from each other
- The limbs behave as linear conductors connected to the trunk, so that an electrode placed anywhere on an extremity is equivalent to one placed at the junction with the trunk.
- electrodes placed on each arm and a leg are then considered to be located at the apices of an equilateral triangle, with the heart at its centre.
- differences in potential recorded between these points represent the projection of vector forces originating from a dipole in the heart, onto lead lines drawn between its apices.

ECG “leads”

- The term ‘lead’ refers to a particular configuration(an imaginary line between two surface electrodes) , NOT to individual electrodes connected to the patient

Lead 1	right arm -ve, left arm +ve
Lead 2	right arm -ve, left leg +ve
Lead 3	left leg +ve, left arm –ve



The +ve electrodes are placed so that depolarisation typically spreads towards them

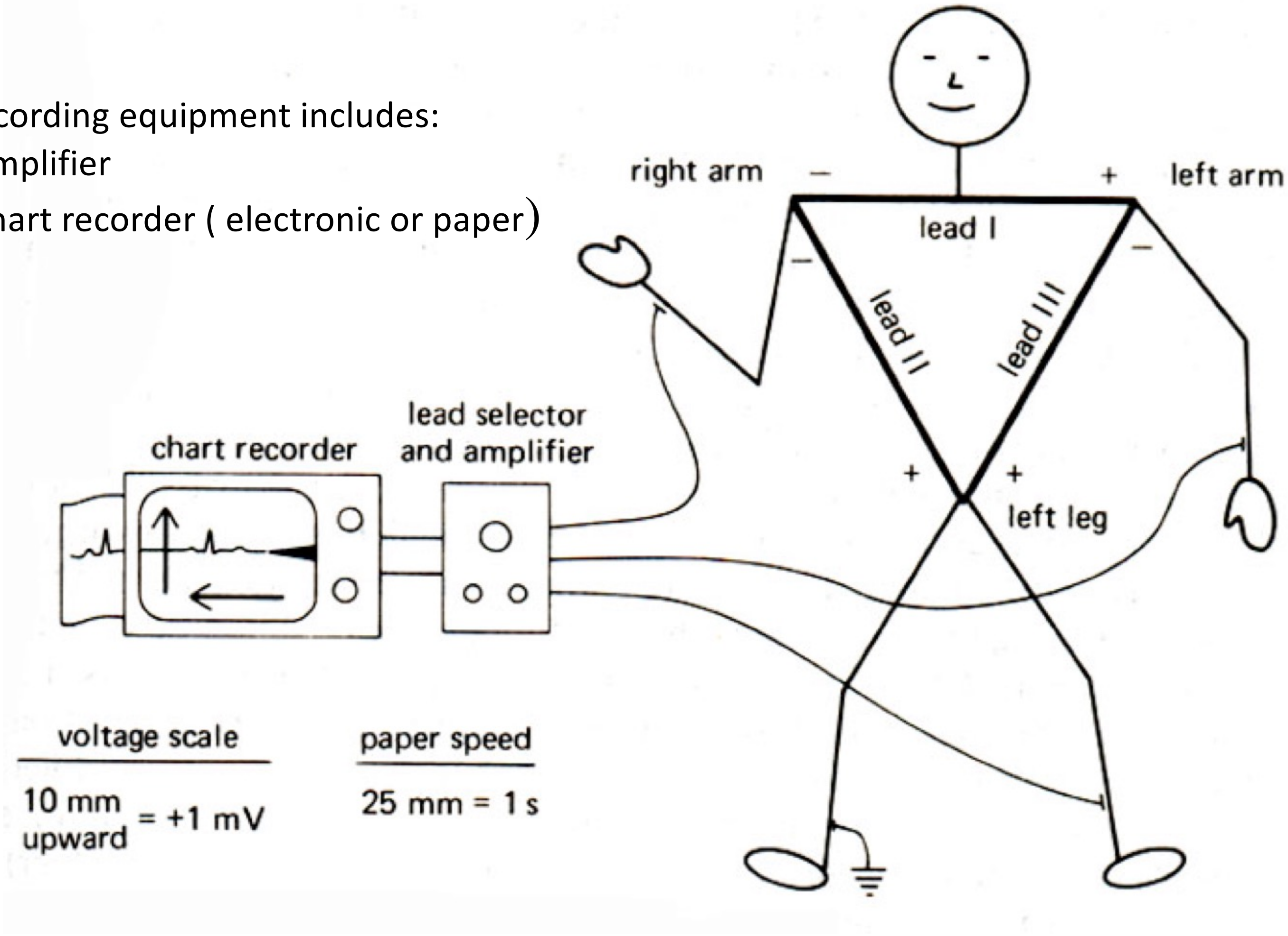
Electrocardiograph set up

- By convention, positive current flow indicates current flow from negative to positively charged area.

- The trace records the difference in potential between the two electrodes.

Recording equipment includes:

- •Amplifier
- •Chart recorder (electronic or paper)



Limitations to Einthoven's hypothesis

- The body does not form a true homogenous electrical conductor, so dispersion of electrical currents is not uniform.

- the heart is often not in the centre of an equilateral triangle, so recording electrodes are not equidistant from the heart.

- in quadrupeds:
  - limb arrangement is much less like an equilateral triangle
  - anatomical attachment of forelimbs to the body is different;
  - moving limbs alters amplitude and direction of potentials.

Limitations to Einthoven's hypothesis

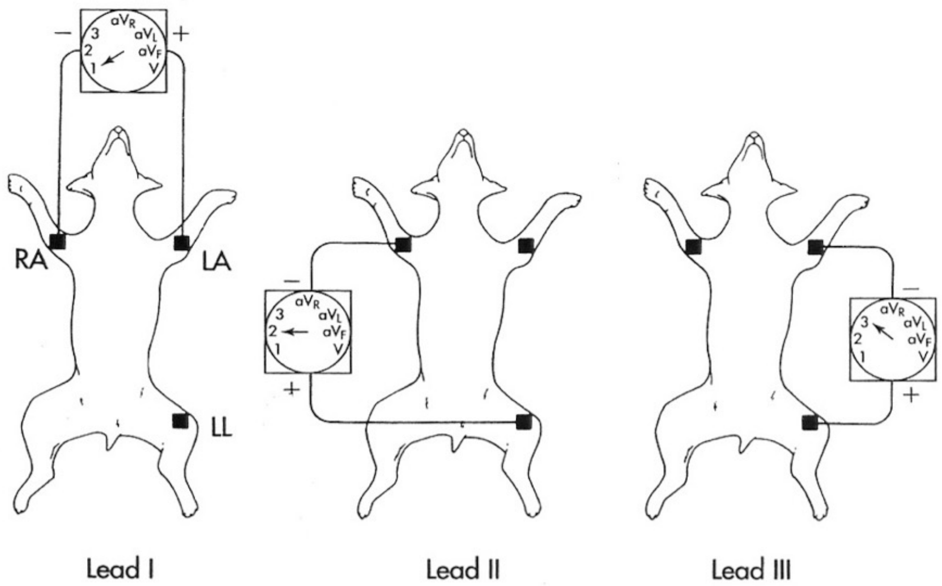


FIGURE 5-13 The three bipolar limb leads and the placement of their electrodes. (From Tilley LP: *Essentials of canine and feline electrocardiography,* ed 3, Philadelphia, 1992, Lea & Febiger.)

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Wave form of the ECG

- represents the net vector of depolarisation and repolarisation of the heart over time

- The shape of the trace depends on the net direction of the wave front of depolarisation, and the amount of tissue that is depolarising.

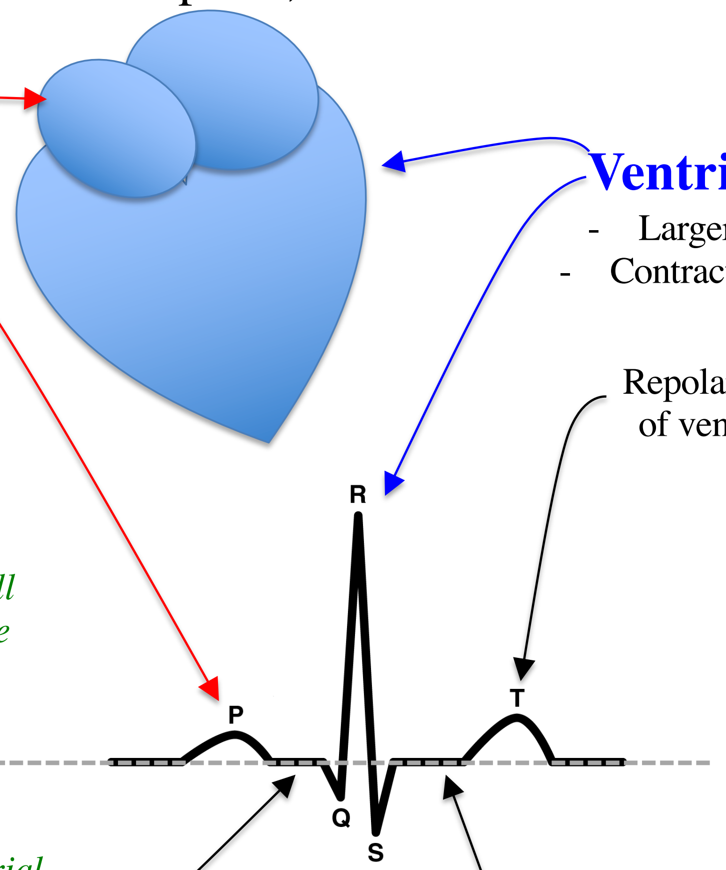
Heart is a muscle with 2 distinct parts;

Atria

- Smaller mass
- Contract first

Ventricles

- Larger mass
- Contract second



Repolarisation of ventricles

Therefore ECG should have a small recording followed by a bigger one

Baseline

What is happening between ***P*** *(atrial depol.) and* ***R*** *(ventricular depol.) ?*

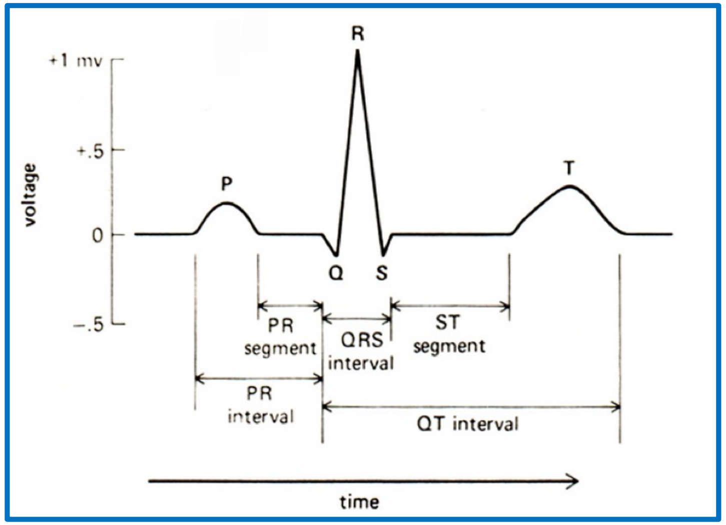
P-R = AV node conduction

What is happening between ***S*** *and* ***T*** *?*

Ventricles are fully depolarised

General features of the ECG trace

- ECG trace has three main components:



- P wave   depolarisation of atria
- QRS complex   ventricular depolarisation
- T wave   ventricular repolarisation

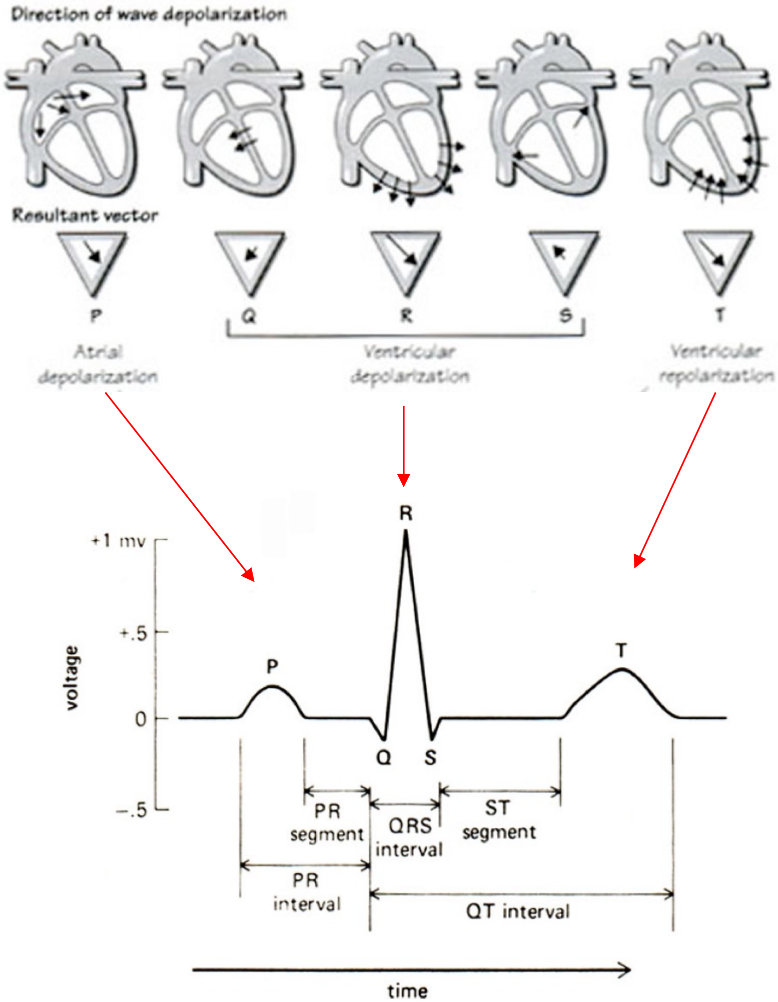
P-R Segment and S-T segment: are normally iso-electric
i.e. no current flowing because tissues (either atria or ventricles) are either all depolarised or all at rest

P-R interval: delay between atrial and ventricular depolarisation, due to delay in AV node.
Prolongation suggests atrial damage or AV block

S-T segment: plateau of ventricular muscle action potential

T wave: is extremely variable in domestic animals. Can be positive, negative or notched in normal animals

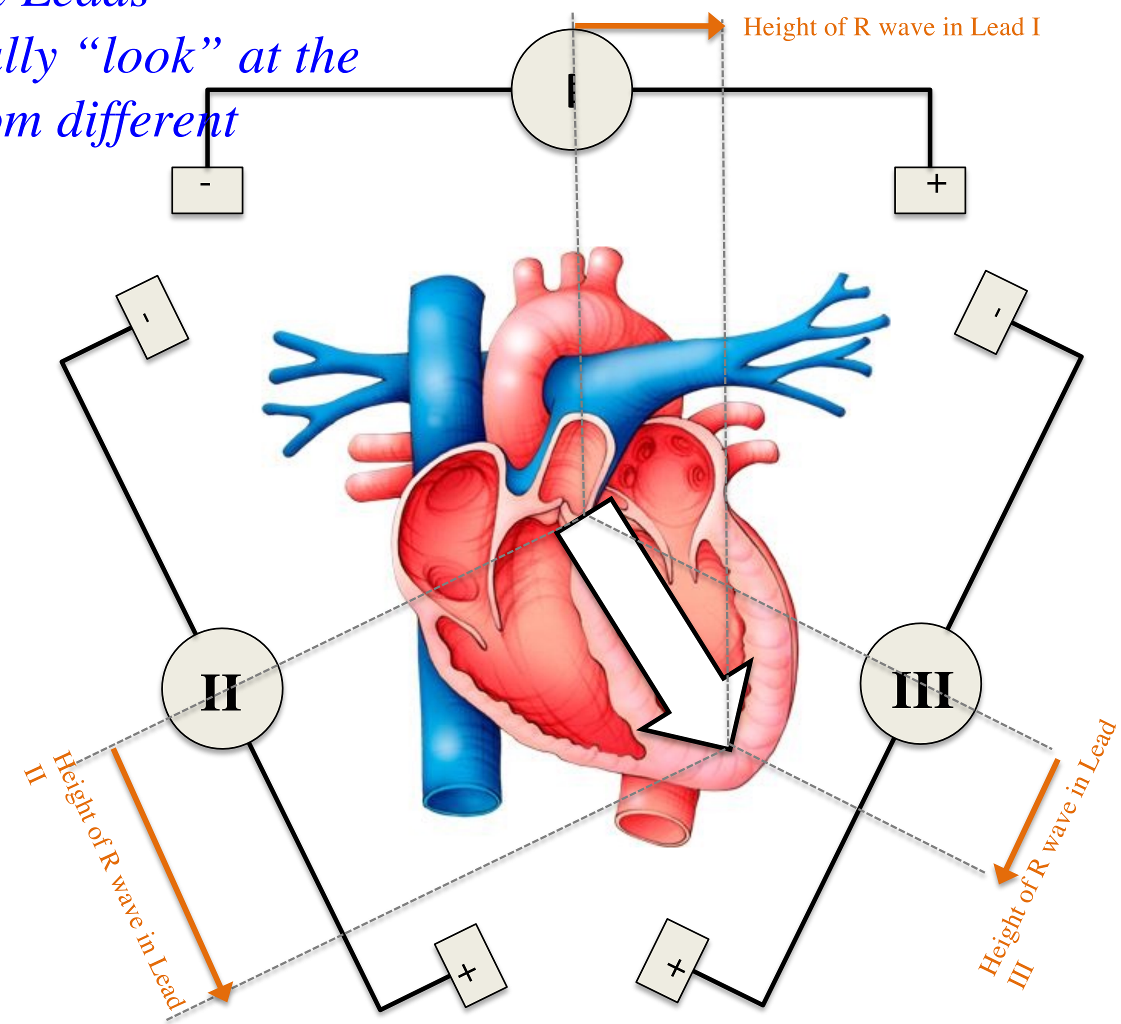
General features of the ECG trace



Aaronson PI & Ward JPT. The Cardiovascular System at a Glance 1999 Ch16

The view we have depends on where we are looking from…

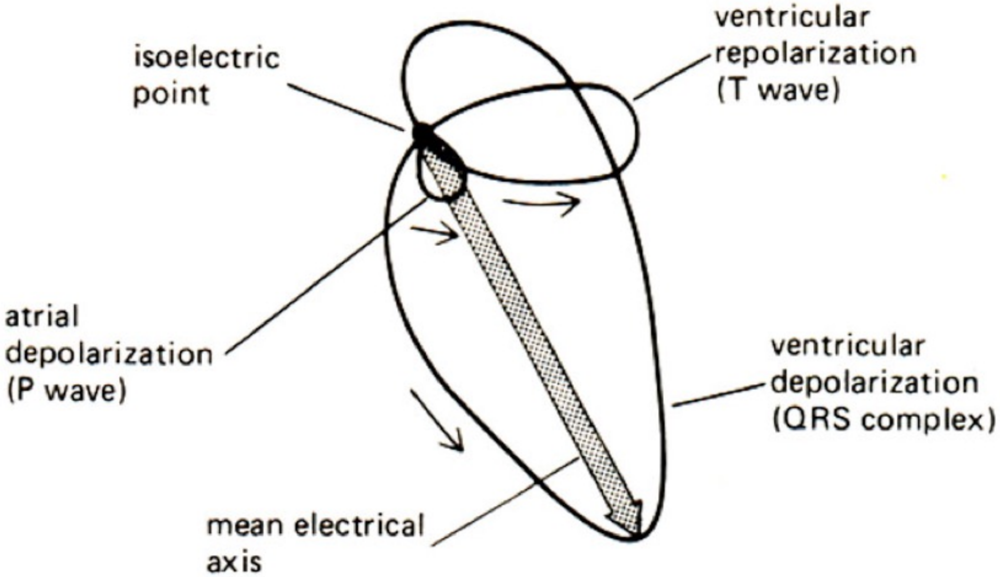
Different Leads electrically "look" at the heart from different angles.



The Lead most parallel to the axis will have the tallest R wave.

Mean Electrical Axis of the Heart

- Is.. the orientation of the ECG vector at its maximum amplitude



Mean Electrical Axis of the Heart

- Is.. the orientation of the ECG vector at its maximum amplitude
- Will be altered by:
  - change in the position of the heart
  - increase in the mass of one of the ventricles

  e.g left ventricular hypertrophy leads to left axis deviation

  right " " " right " "
- Is calculated by mathematical analysis of three bipolar leads

Describing Alterations in Heart Rhythm

- Arrhythmia- alteration in rate or rhythm
- Bradycardia- slowing of heart rate
- Tachycardia- increase in heart rate
- Sinus bradycardia- slowing governed by SA node (due to increased vagal tone)
  - Observed in sleeping individuals, and well-trained athletes
- Sinus tachycardia- increase in HR governed by SA node (due to increased sympathetic tone)
  - Normal during exercise, anxiety states, fever

Describing Alterations in Heart Rhythm

- Sinus arrhythmia-
  - Variations in heart rate synchronous with respiration
  - HR increases towards end of inspiration
  - HR decreases towards end of expiration
  - Common and normal observation at rest
  - At higher heart rates sinus arrhythmia disappears

Abnormal Rhythms Resulting from Block in Impulse Conduction

- Sinoatrial block: impulse blocked before it enters atrial muscle so no P wave
- Atrioventricular block:
  - transmission through AV node either slowed or completely impeded
  - P waves not always related to QRS complex

Atrio-ventricular Block

First degree:

- unusually slow conduction through AV node
- detected by abnormally long PR interval

Second degree:

- some but not all impulses are transmitted through the AV node
- atrial rate is often faster than ventricular by a certain rate (e.g.2:1, 3:1)
- depending on ventricular rate may not be a serious problem.

Third degree:

- complete block, with complete dissociation of P wave and QRS complex
- some area in the ventricles (often in Bundle Branch) assumes pacemaker role
- ventricular rate likely to be slower than normal

Abnormal Rhythms caused by premature beats

- Premature atrial contractions:
  - An area of the atria “escapes” normal pacemaker domination and initiates a heart beat
  - May or may not be followed by a ventricular contraction
- Premature ventricular contractions (VPC’s)
  - Not preceded by P wave
  - Often followed by missed beat as muscle is refractory when normal impulse arrives
  - premature beat has reduced stroke volume, delayed beat larger than normal stroke volume

Paroxysmal Tachycardias

- A tachycardia arising from an ectopic pacemaker
- Onset and termination normally abrupt
- May arise in:
- Atria or AV node
  - called "supraventricular" as they are indistinguishable
- Ventricles
  - called paroxysmal ventricular tachycardia
  - more serious: ventricular filling and contraction incomplete
  - May progress to fibrillation

Fibrillation

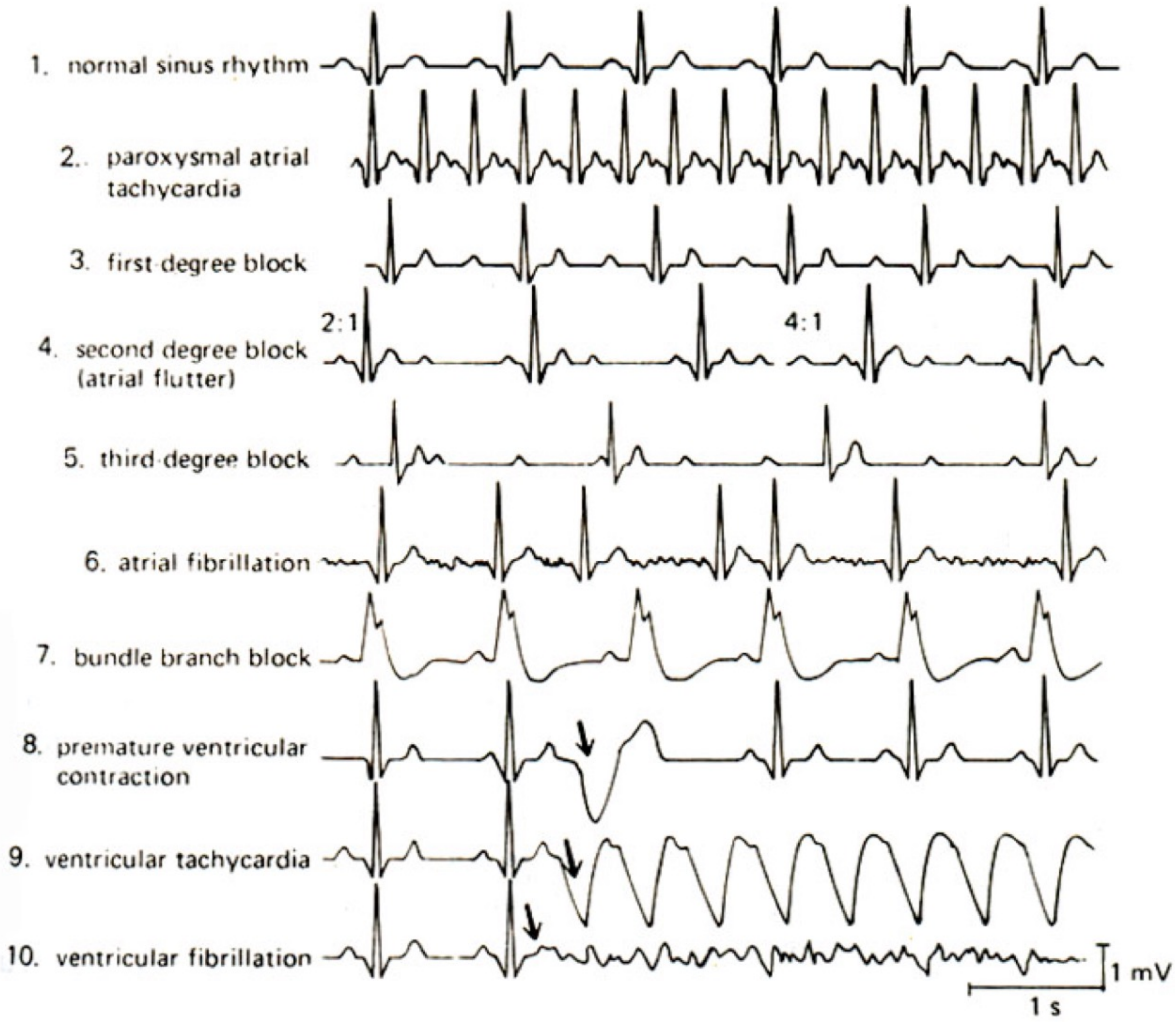
Rapid completely disorganised conduction pathways

- Atrial fibrillation leads to
  - Disorganised atrial activity and conduction
  - Irregular ventricular rhythm
  - No P waves on trace
  - Reversible with medication

Fibrillation

Rapid completely disorganised conduction pathways

- Ventricular fibrillation
  - much more serious
  - may result from electric shock, major myocardial infarction, (loss of blood supply) certain anaesthetic agents, handling the heart during surgery
  - loss of consciousness within a few seconds
  - resuscitate with electric shock- place entire myocardium in refractory state and give SA node chance to take over as pacemaker again



1. normal sinus rhythm
2. paroxysmal atrial tachycardia
3. first-degree block
2:1
4:1
4. second degree block (atrial flutter)
5. third-degree block
6. atrial fibrillation
7. bundle branch block
8. premature ventricular contraction
9. ventricular tachycardia
10. ventricular fibrillation
1 mV
1 s

What's Important?

- What does an ECG measure
- How is an ECG possible?
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- How good was Einthoven?
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- Normal and abnormal rhythms