# Understanding the ECG

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Prac 2

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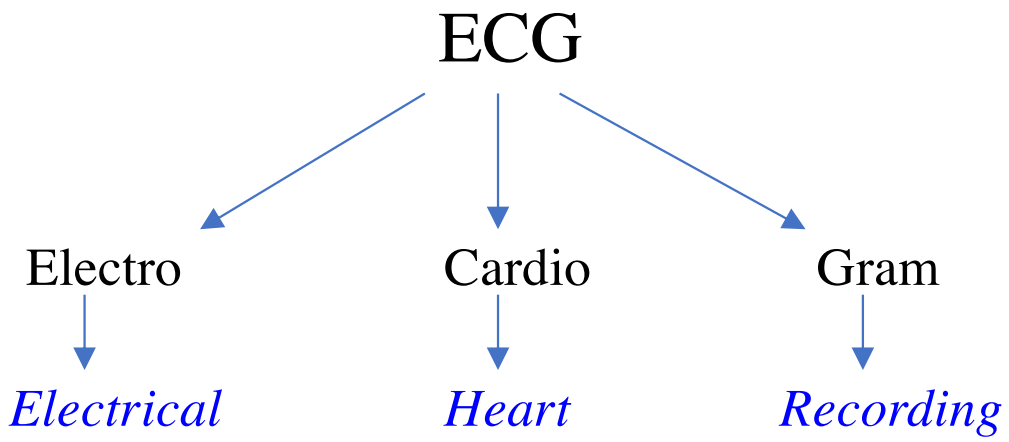
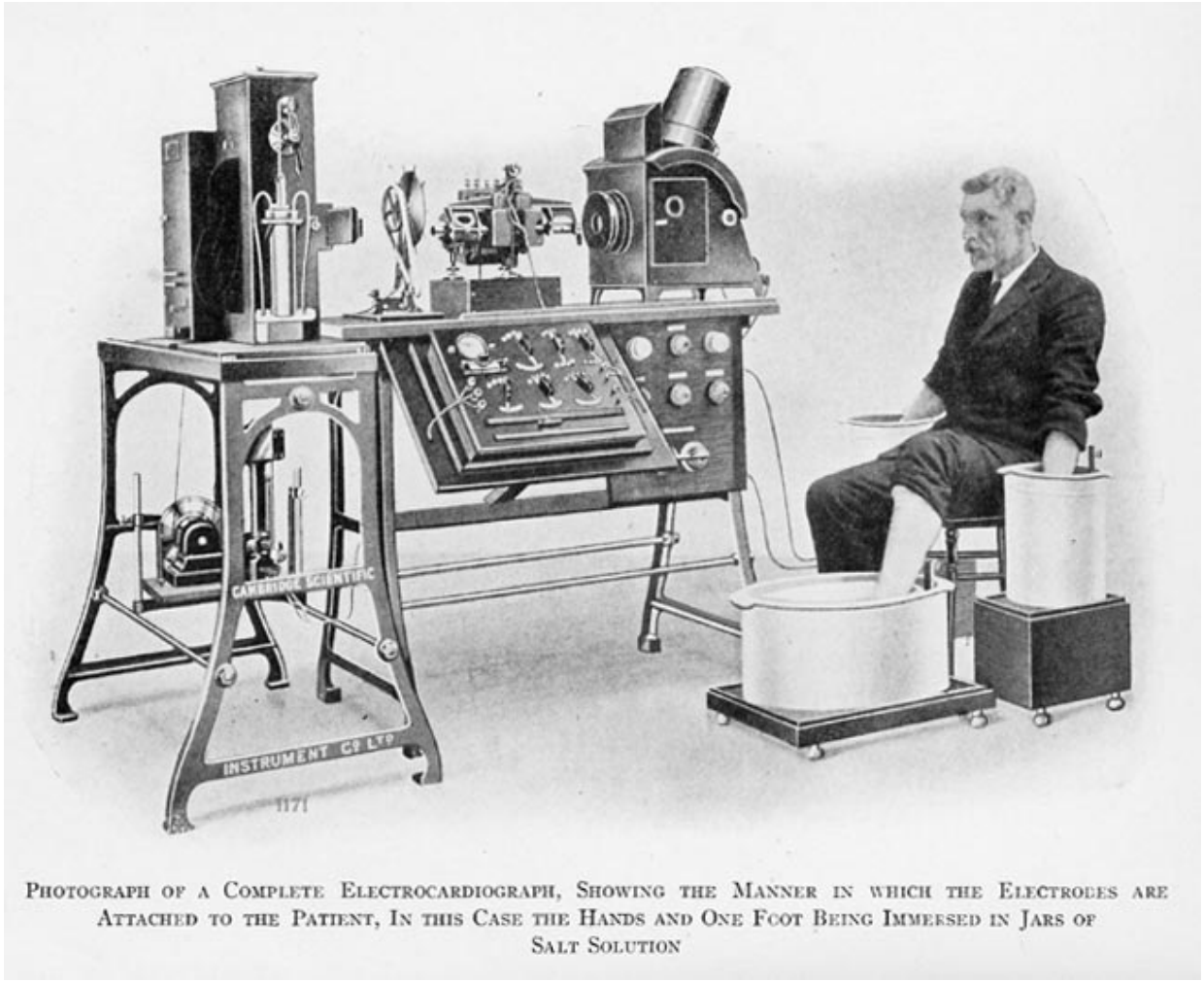
# Objectives of Today's Class

- To develop a sound understanding of the ECG
  - How is it created?
  - What does it represent?
  - What are its limitations?




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

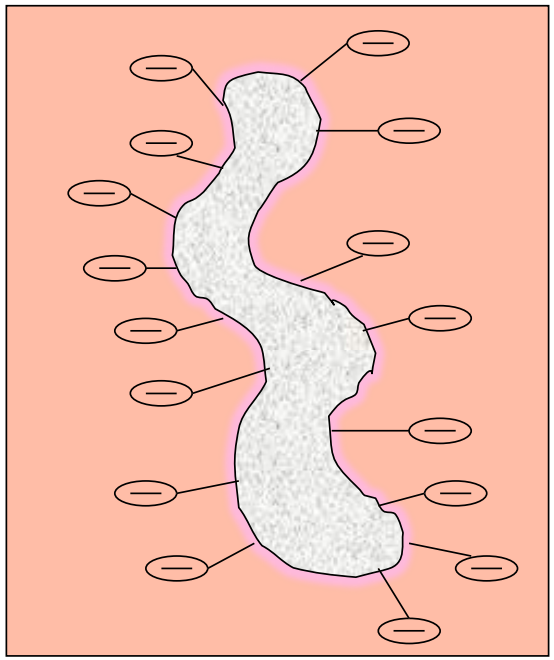
# The basis of the electrocardiogram

- 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

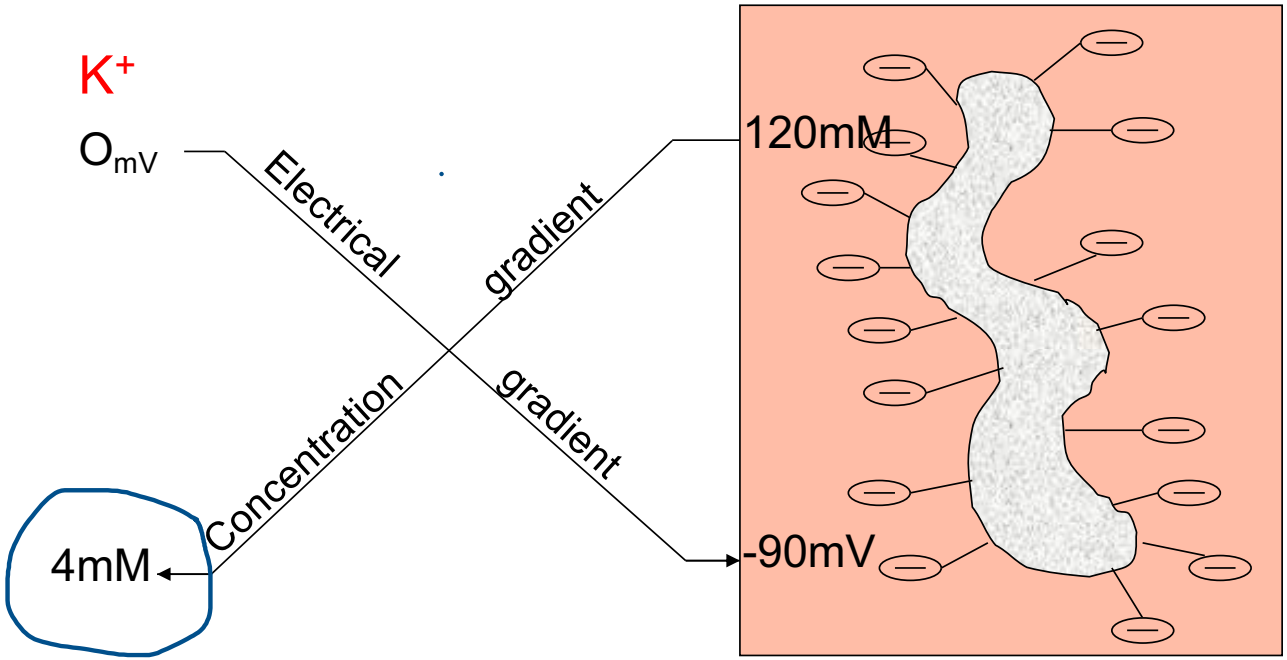
# Why does a Resting Cell have a membrane potential?

1. Proteins are
   - Fixed, intracellular
   - Negatively charged



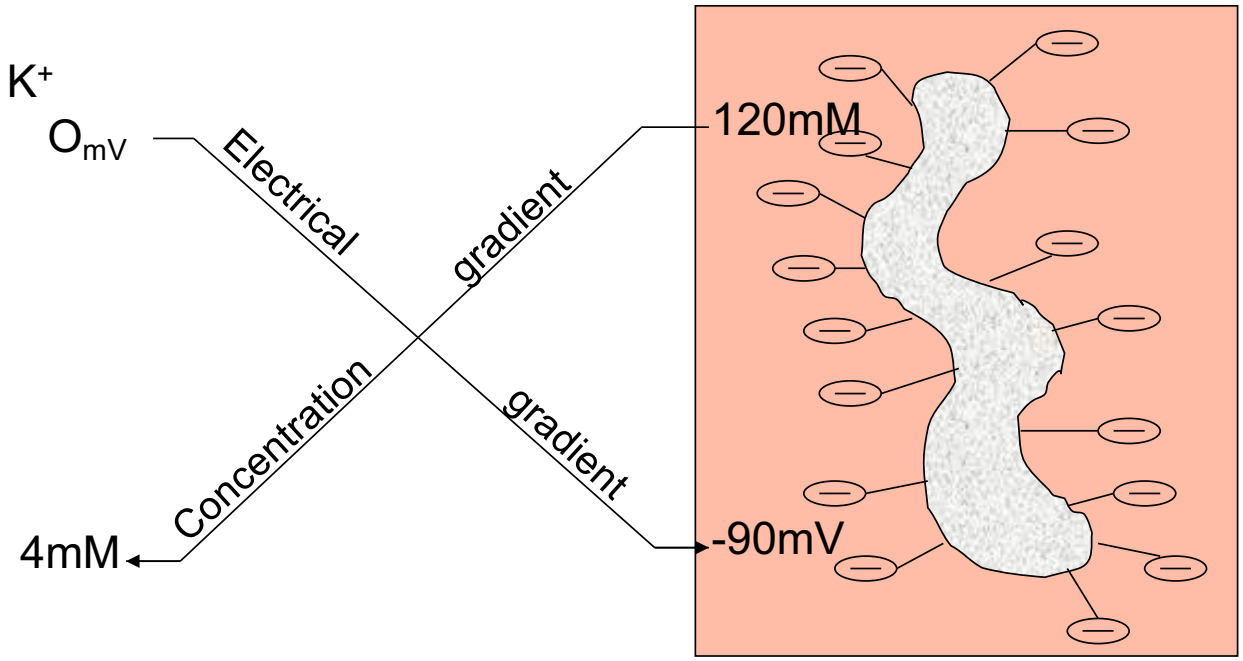
# Why does a Resting Cell have a membrane potential?

2. $K^+$ ions can move freely- cell membrane is permeable to potassium




K+ ions move down their electrical gradient into the cell, and equilibrate with K+ ions moving out of the cell down their concentration gradient

1. Proteins
   - Fixed, intracellular
   - Negatively charged
2. $K^+$ ions can move

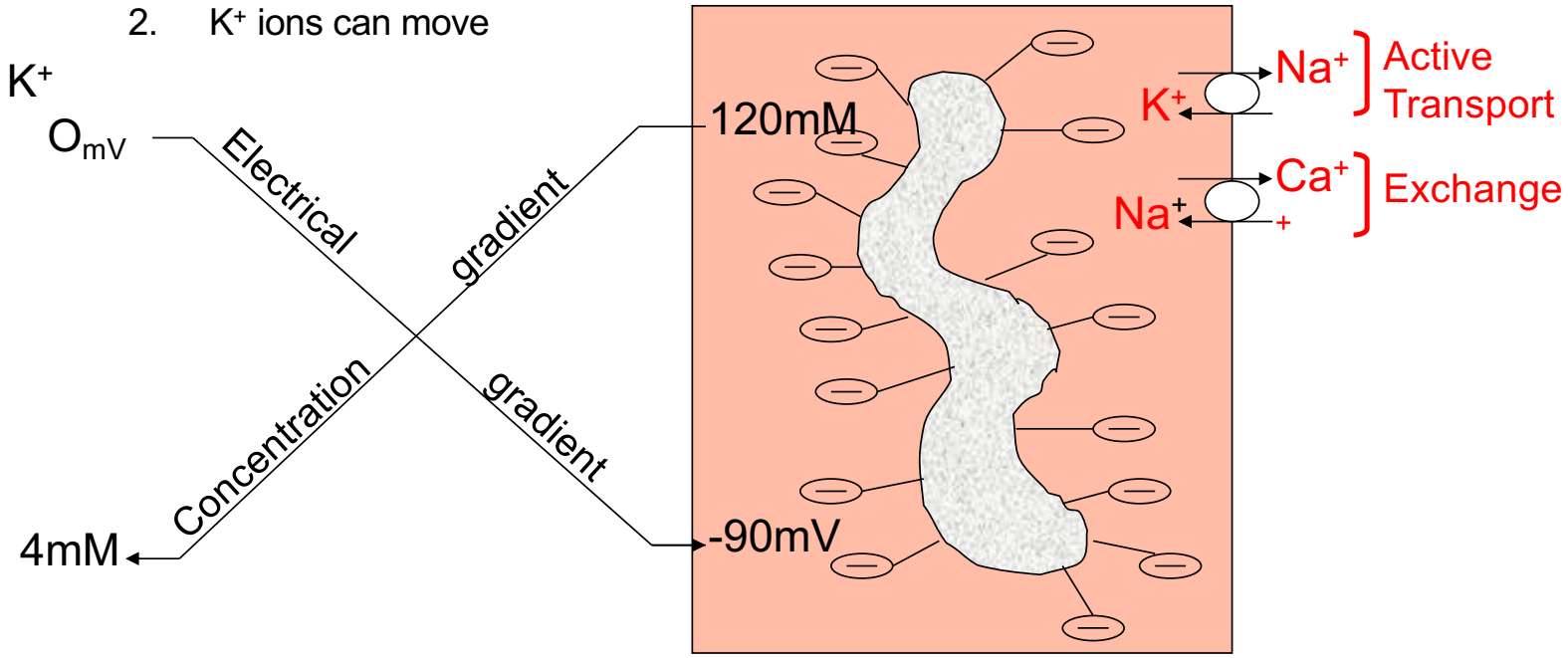



From the Nernst equation:
Membrane potential at equilibrium

$$V_m \propto \frac{-\log [K_i^+]}{[K_o^+]} = -90 \text{ mV}$$

# Resting Cardiac myocyte - other ion pumps

1. Proteins
   - Fixed, intracellular
   - Negatively charged
2. $K^+$ ions can move



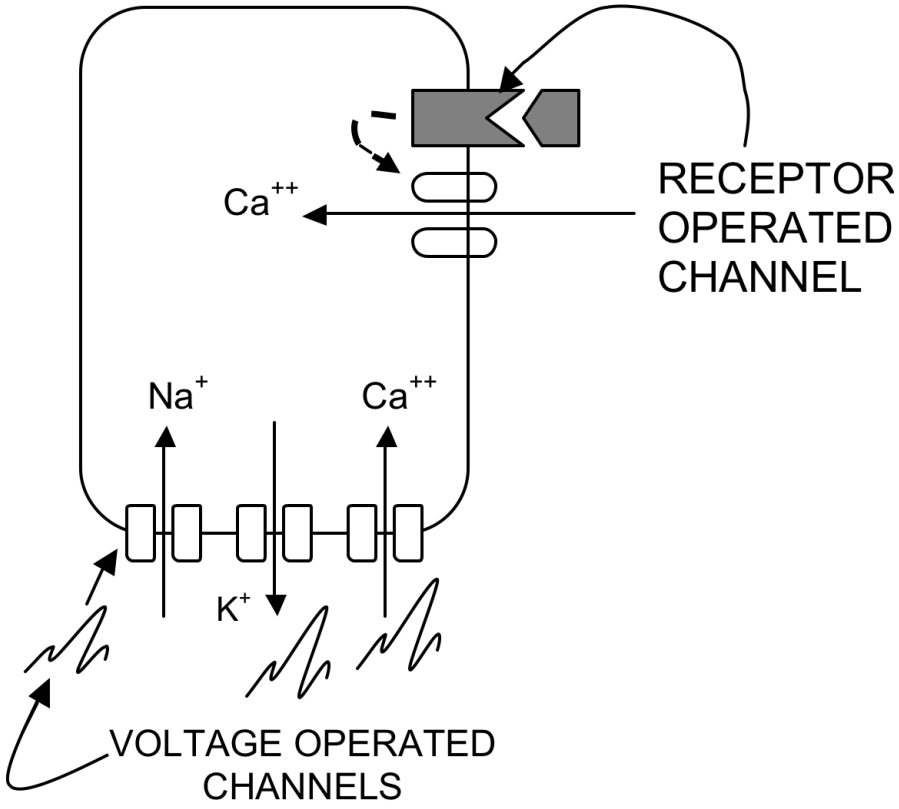

From the Nernst equation:
Membrane potential at equilibrium

$$V_m \propto \frac{-\log [K_i^+]}{[K_o^+]}$$

# The Action Potential in Cardiac Myocytes

- Ion channels provide for selective movement of particular ions into the cell
- These may be-
  - Receptor operated ion channels
  - Voltage operated ion channels. These are "gated" (opened and closed) by changes in membrane potential- once opened they are almost immediately inactivated

# Ion channels and the generation of an action potential

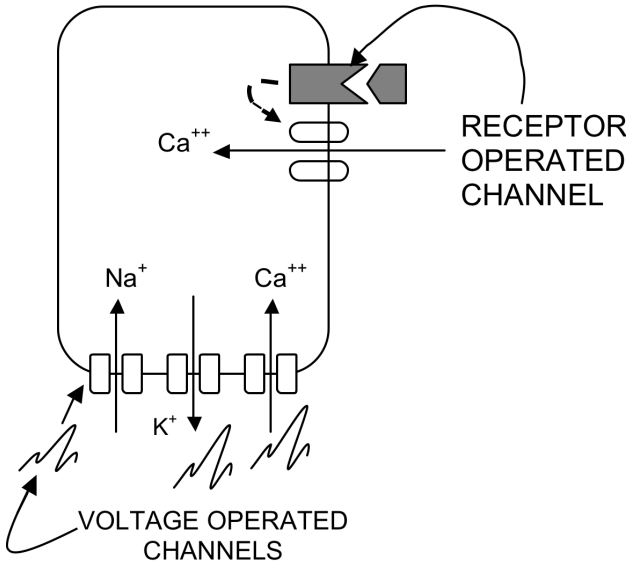


# Ion channels and the generation of an action potential

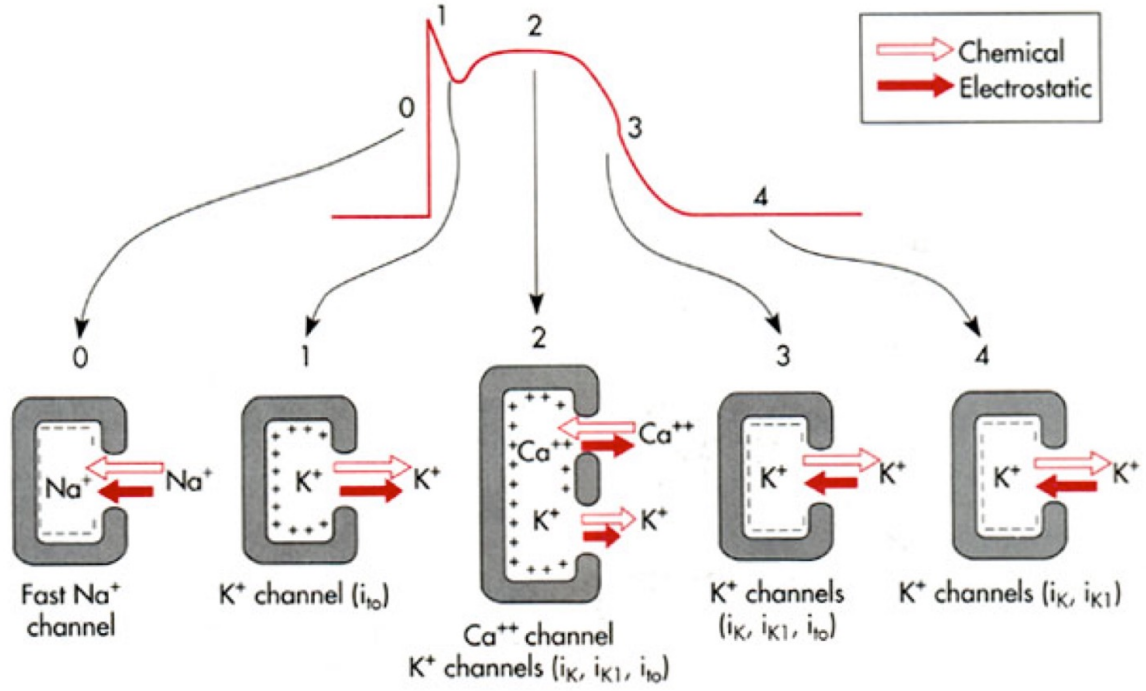
- In both cardiac and smooth muscle, the action potential depends on the entry of Na and Ca to the cell

- Ions enter the cell passively down their concentration gradient

- The interior of the cell becomes more positive- hence **depolarisation** occurs



# The ionic mechanism of the action potential




Berne R.M. & Levy M.N. Cardiovascular Physiology 7th Edition 1997

# 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

- These charge differences relate to the difference in charge on the SURFACE (OUTSIDE) of cardiac cells- not across the cell membrane

- The surface of a RESTING cell is POSITIVE
- The surface of a DEPOLARISED cell is NEGATIVE

- By convention current flow from negative to positive electrode is recorded as a positive deflection

# The basis of the electrocardiogram

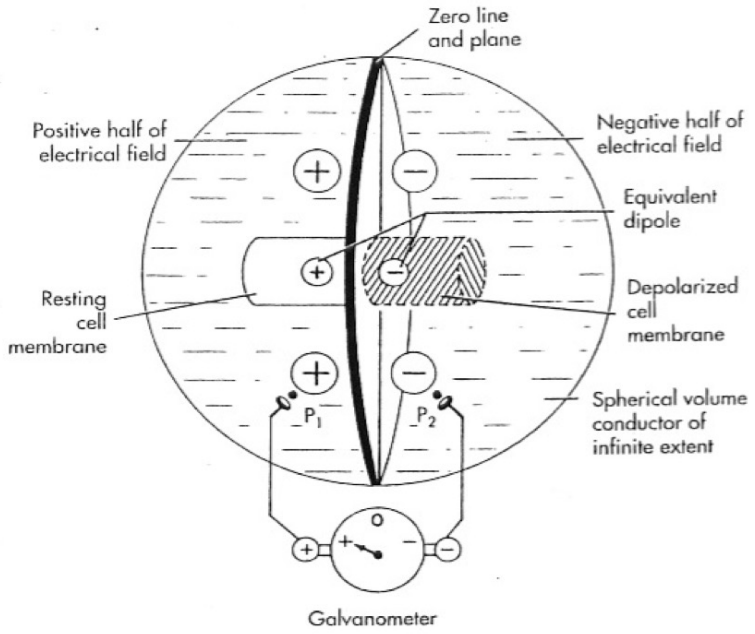



**FIGURE 5-7** Schematic representation of equivalent dipoles along the surface of a wavefront. Two electrodes (+ and –) have been placed on either side of the wavefront and attached to a galvanometer to form a lead and record the electric field. The wavefront is spreading from ~~left to right~~, toward 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

Kittleson MD & Kienle RD Small Animal Cardiovascular Medicine 1998

# 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

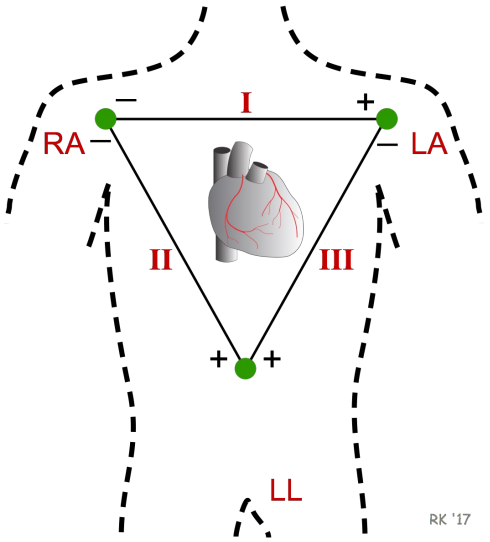
# Einthoven's hypothesis

- 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

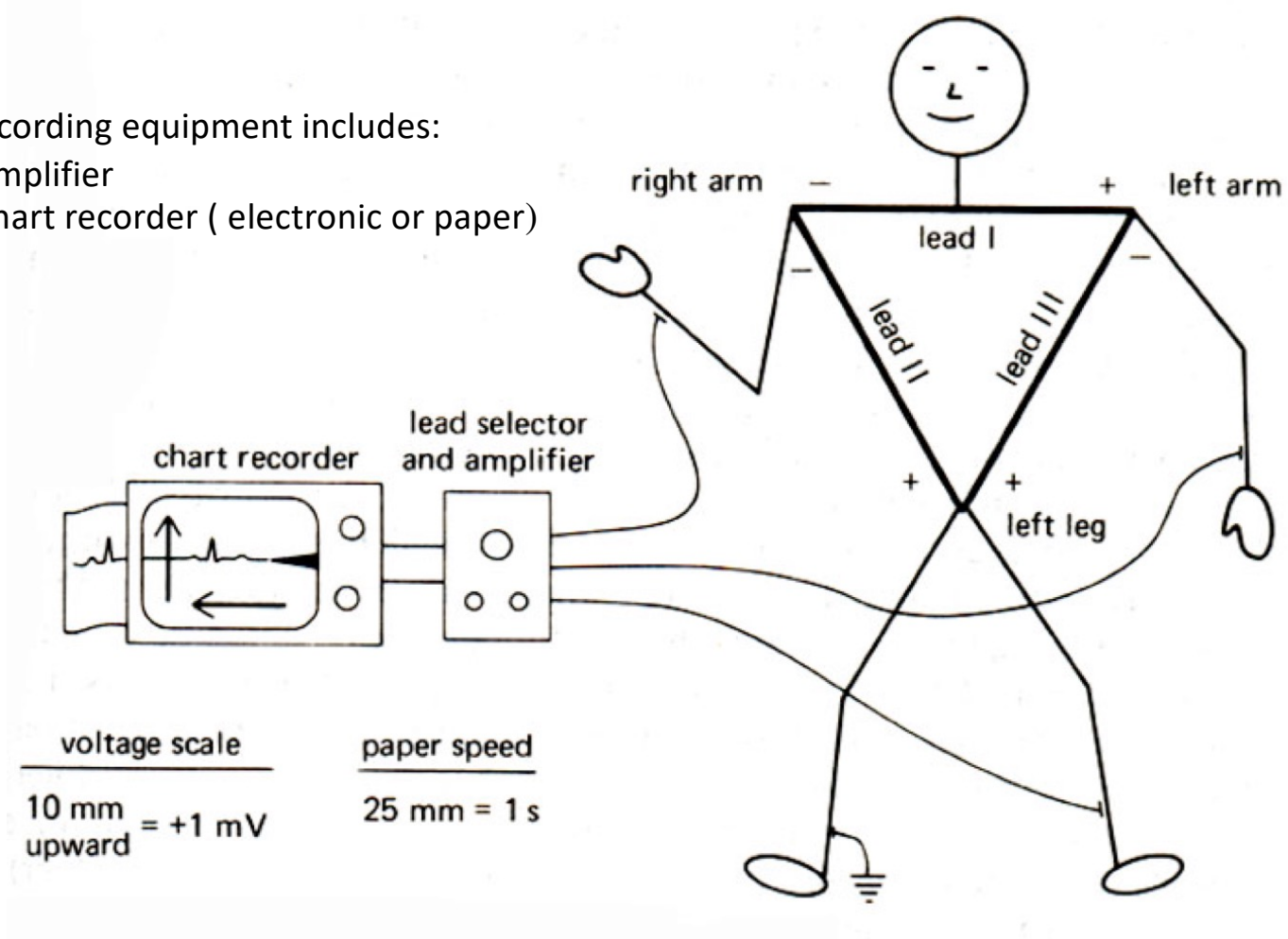
# Electrocardiograph set up

- 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.

# Learning objectives

By the end of this prac class we hope  you should be able to:

•Explain how an ECG is recorded and identify the major components required to make a recording.

•Show the electrode placement to perform a 3 lead ECG.

•Explain the temporal relationship between the ECG and the finger pulse.

•Interpret events in the cardiac cycle, and relate these to features in the ECG and the finger pulse.

•Describe the changes in ECG trace in response to exercise

•Describe how the different "views" of the heart are provided by the 3 leads.

•Assess the reliability of ECG traces obtained from dogs, and the variability introduced by changes in limb position

•Explain why Einthoven's hypothesis applies less well to quadrupeds than humans

# … or more simply…

- To develop a sound understanding of the ECG
  - How is it created?
  - What does it represent?
  - What are its limitations?