FYS 4250

Lecture 2



Case 2



- 47 years old male, no chronic diseases, father died from cerebral hemorrhage 63 years old. His mother is still alive, no diseases.

Case 2

- The patient comes to the emergency room complaining of severe shortness of breath and coughing, several episodes in the past, lasting a day or two.
- He had an episode of rheumatic fever at age 14 years, denies any abuse of drugs or alcohol, no tobacco. On examination, heart rate is between 110 – 130 bpm, respiratory rate of 24 breaths per minute, with oxygen saturation of 92% oxygen. Coughing, producing frothy sputum with a pinkish tint. Bilateral inspiratory crackles can be heard in the lower lung fields.

- What is the most likely diagnosis?

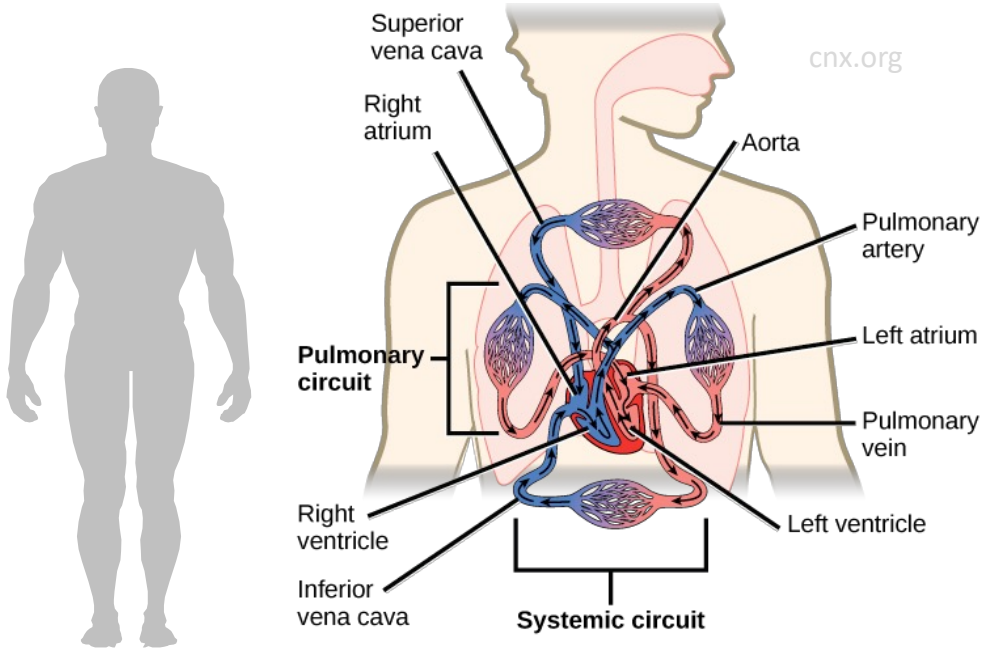
Case 2

- Seems reasonable that the problems are related to the heart or the lungs. Typically an examination will start with the heart to exclude any possible life-threatening arrythmias

- What will you do now?

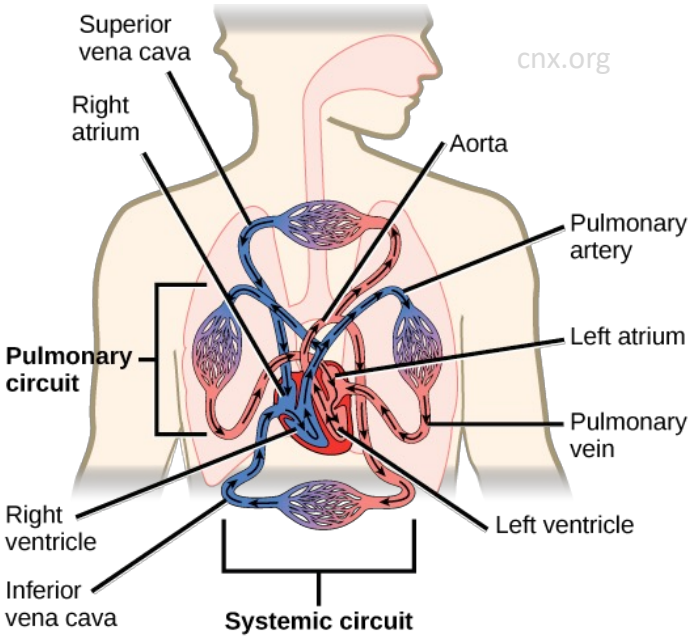
Case 1

- Electrocardiogram, ECG = measuring the electrical activity of the heart



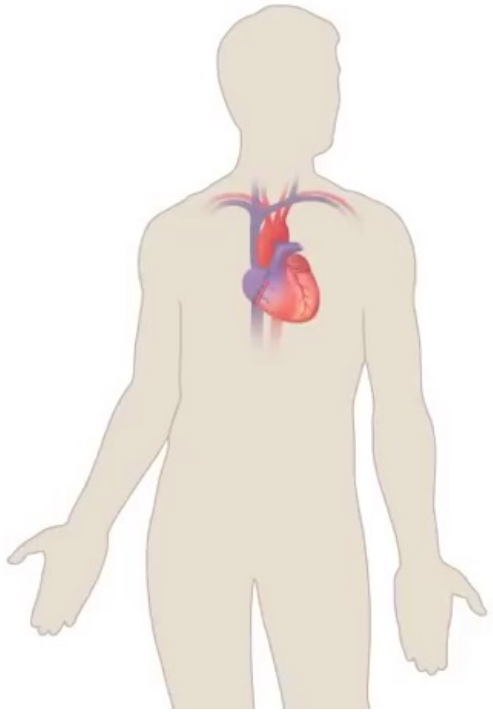
ECG

- Electrocardiogram, ECG = measuring the electrical activity of the heart



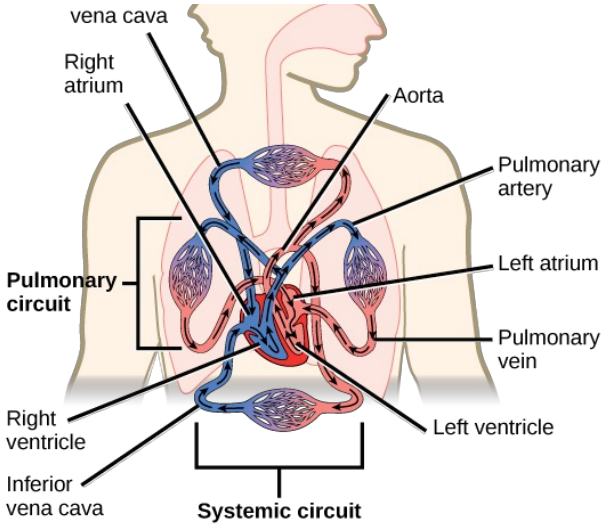
- How is the electrical activity generated?

The circulatory system



Video: Mayo clinic

Exercise



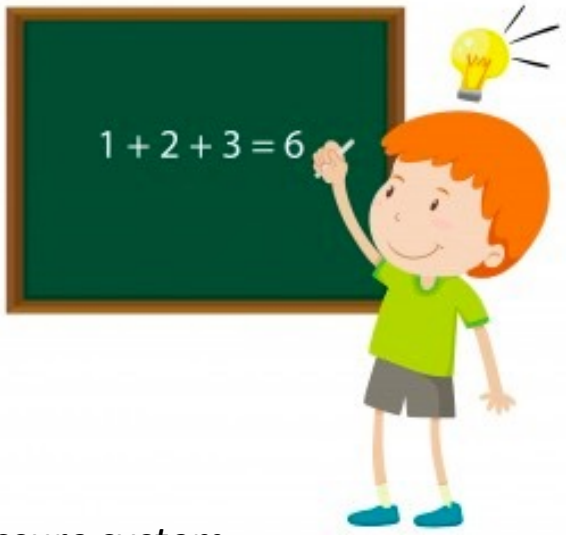
Form groups of 2 or 3 students, and discuss:

a. In such a complex hydrodynamic system as the cardiovascular system, how can we be sure the blood goes in the right direction all the way?
b. If the pressure in the right atrium is elevated, what is typically wrong?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

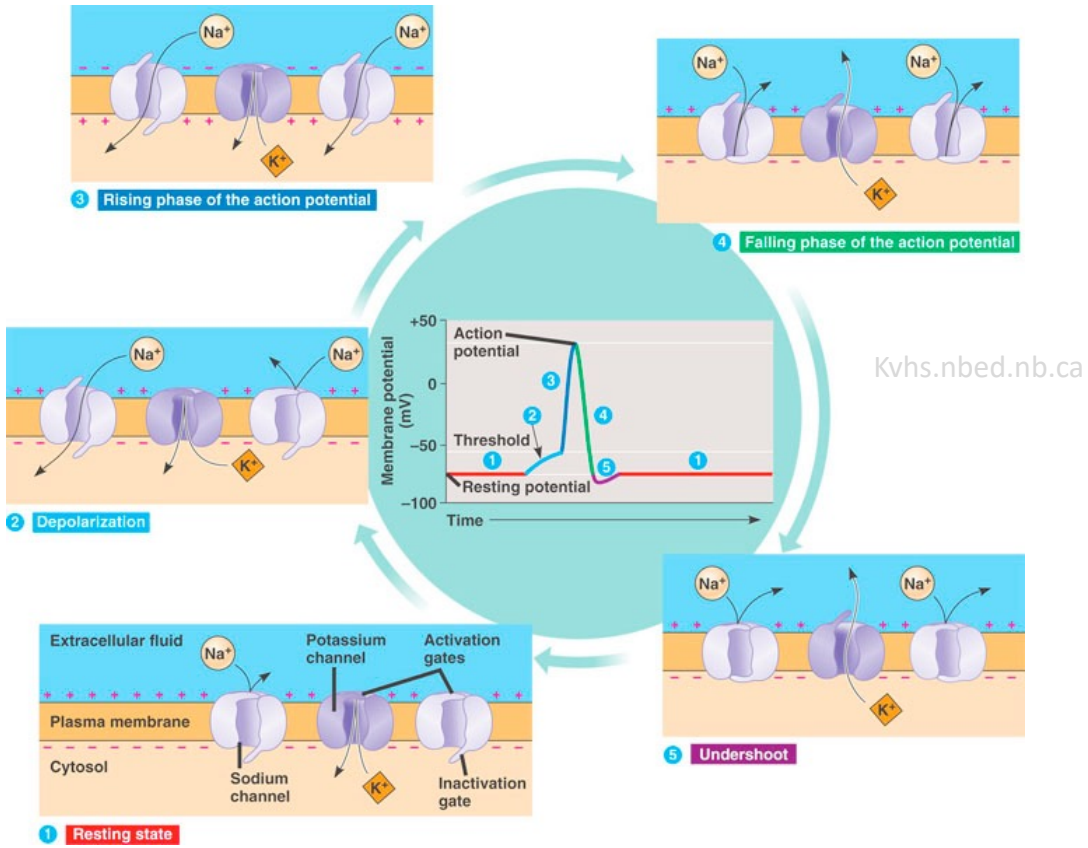
Answer



a. There are valves of veins in the low pressure system

b. Typically, there is a major obstruction in the lung artery somewhere, like a pulmonary embolism

Action potential of a single heart cell



Kvhs.nbed.nb.ca

Action potential of a single heart cell

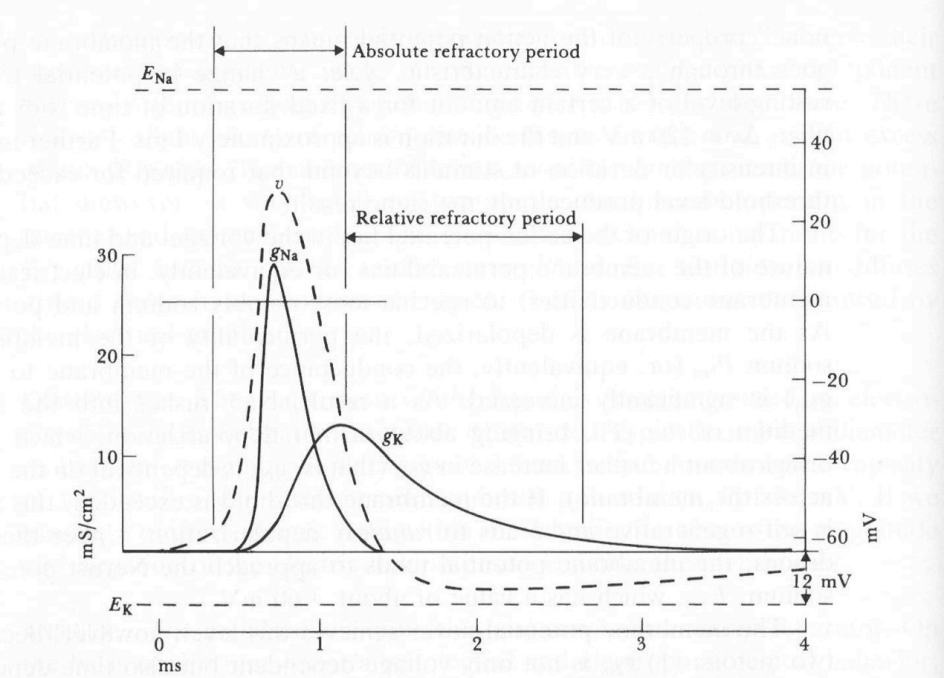
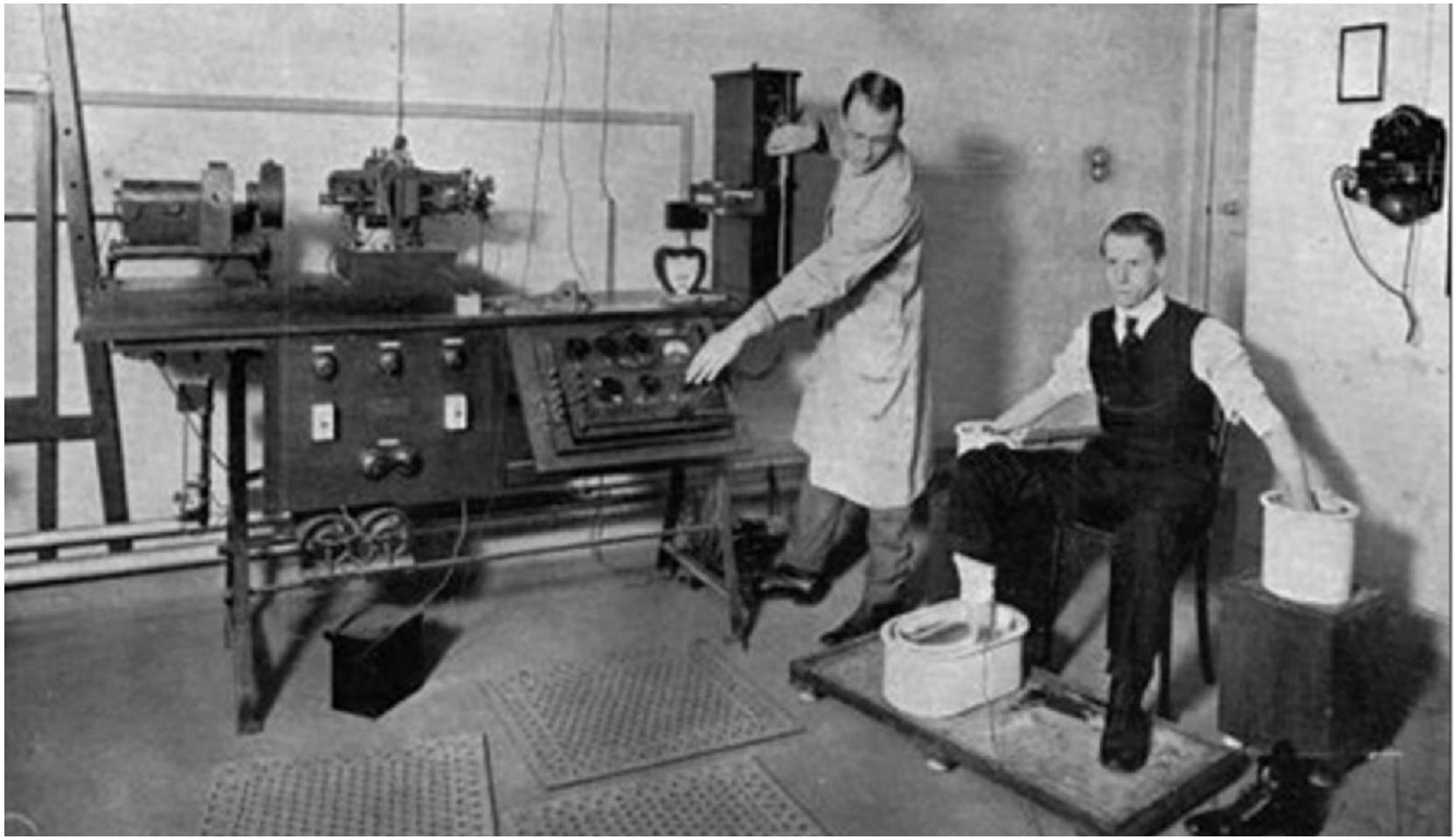


Figure 4.2 Theoretical action potential v and membrane ionic conductance changes for sodium (g_{Na}) and potassium (g_K) are obtained by solving the differential equations developed by Hodgkin and Huxley for the giant axon of the squid at a bathing medium temperature of 18.5°C. E_{Na} and E_K are the Nernst equilibrium potentials for sodium and potassium across the membrane. (Modified from A. L. Hodgkin and A. F. Huxley, "A Quantitative Description of Mem-

Wilhelm Einthoven, the invention of the ECG

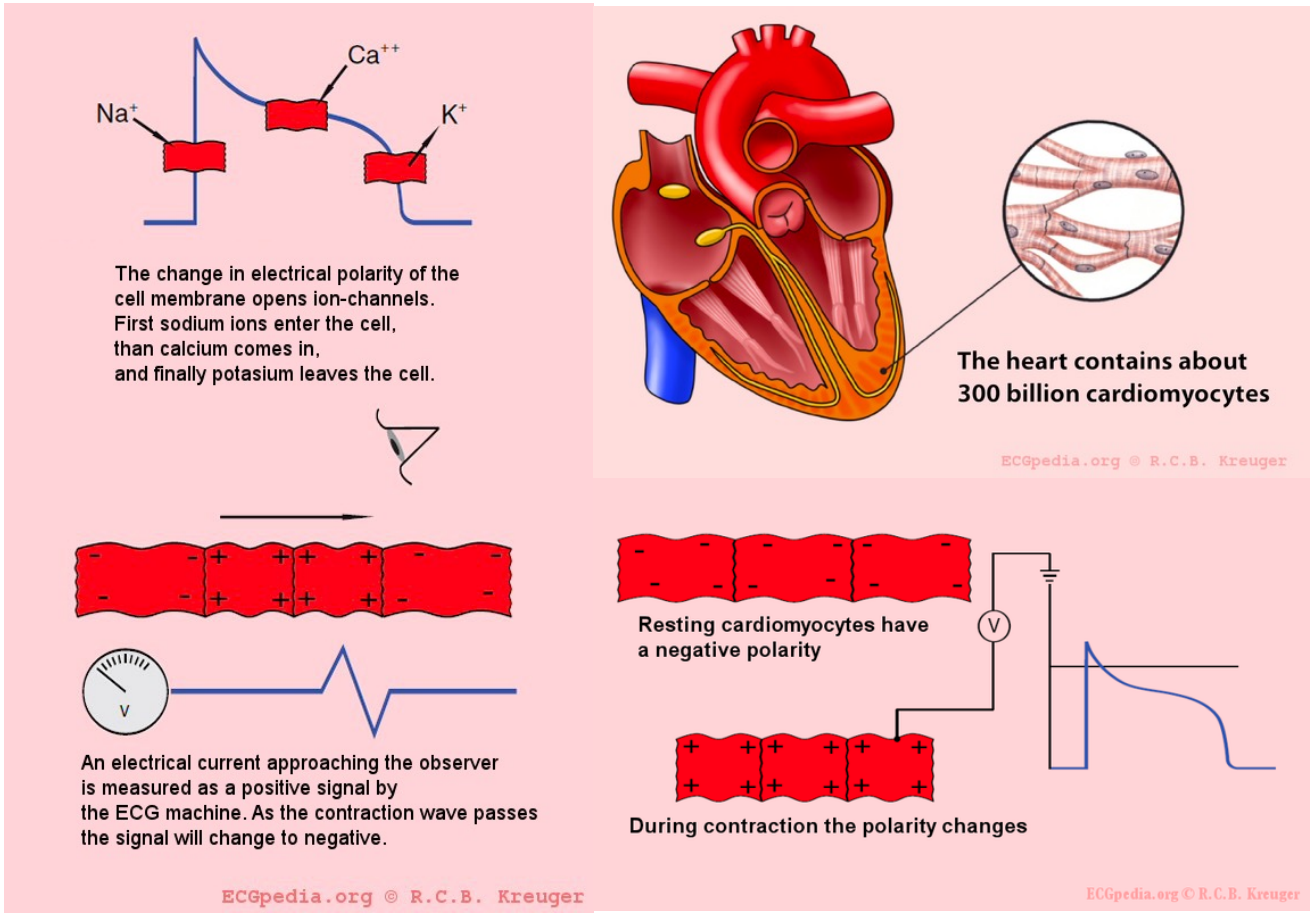


String galvanometer (1916)

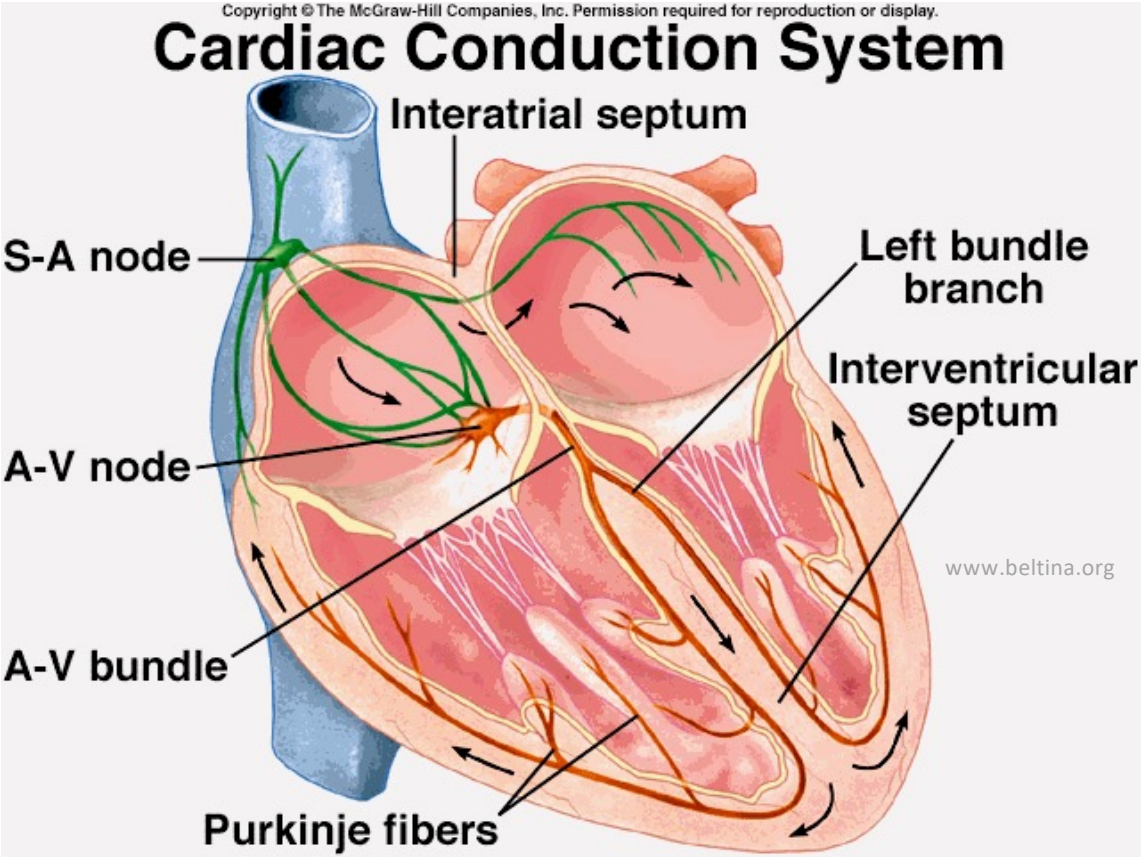
Source: Heart Views, 2019, the invention of the ECG machine

ECG-Basics

(ECGpedia.org)



Cardiac conduction system



- How is this seen as an ECG?

Regional electric activity

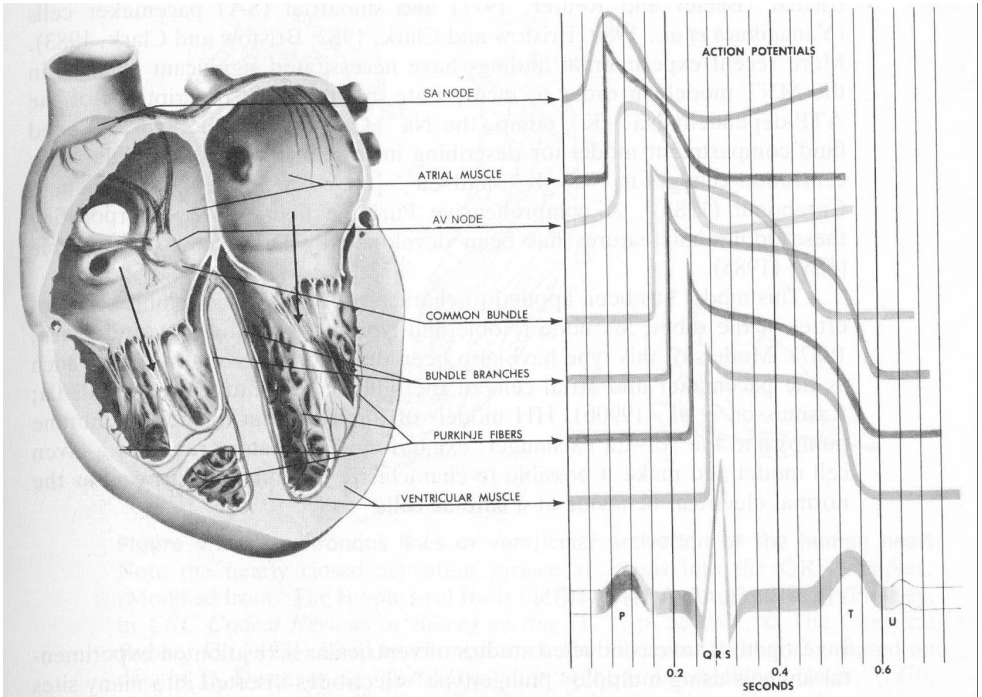
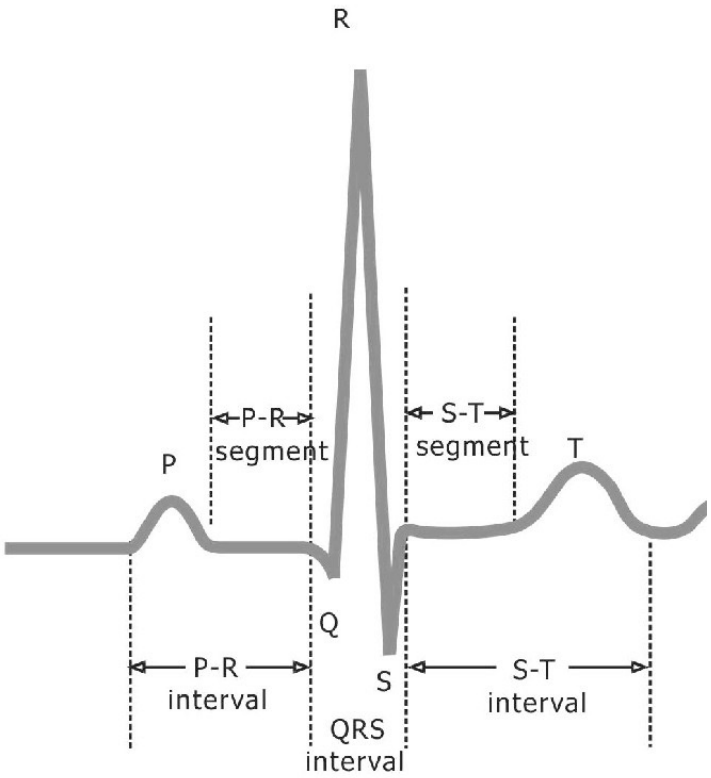


Figure 4.14 **Representative electric activity from various regions of the heart** The bottom trace is a scalar ECG, which has a typical QRS amplitude of 1–3 mV. (© Copyright 1969 CIBA Pharmaceutical Company, Division of CIBA-GEIGY Corp. Reproduced, with permission, from *The Ciba Collection of Medical Illustrations,* by Frank H. Netter, M.D. All rights reserved.)

- What does the final signal look like?

The ECG-complex



P-wave = atrial depolarisation

PR-segment = impulse from atria to ventricles

QRS-complex = ventricular depolarisation

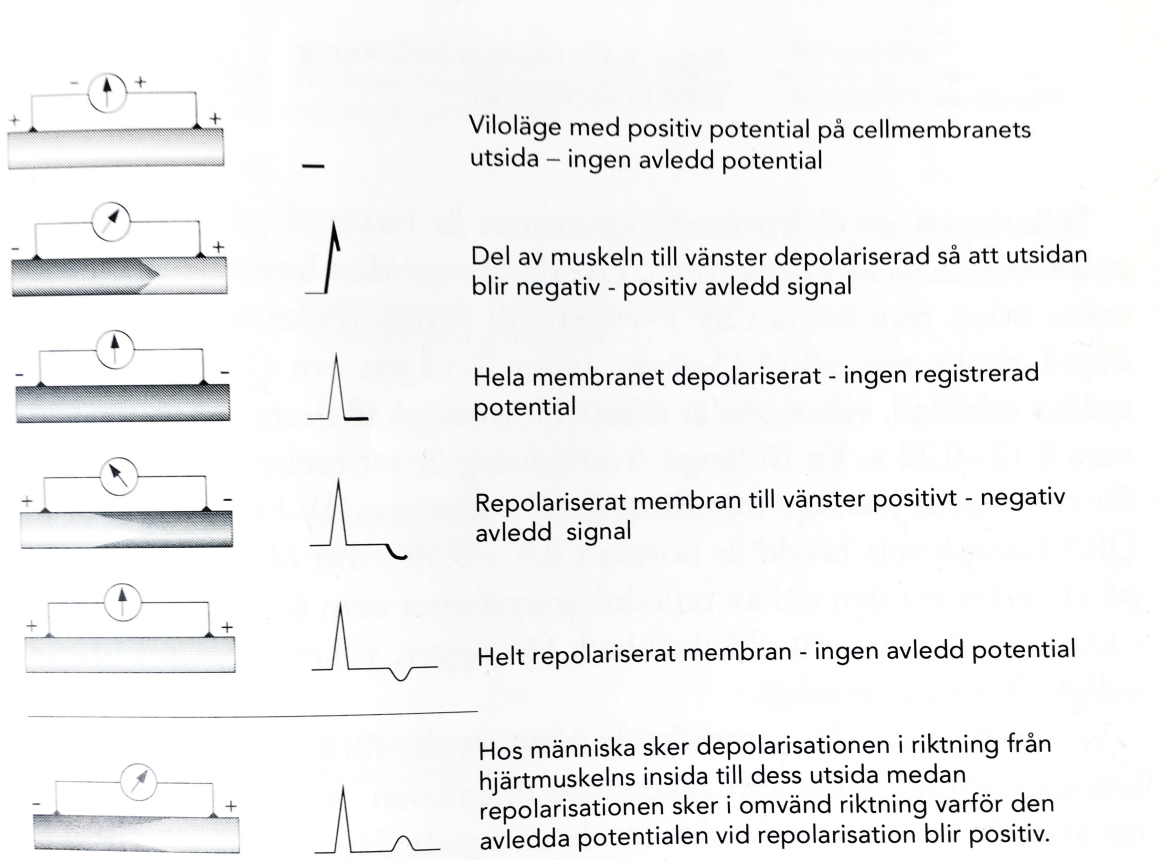
ST-segment = isoelectric – part of repolarisation

T-wave = ususally same direction as QRS – ventricular repolarisation

QT-interval = This interval spans the onset of depolarisation to the completion of repolarization of the ventricles

- How can we obtain this signal?

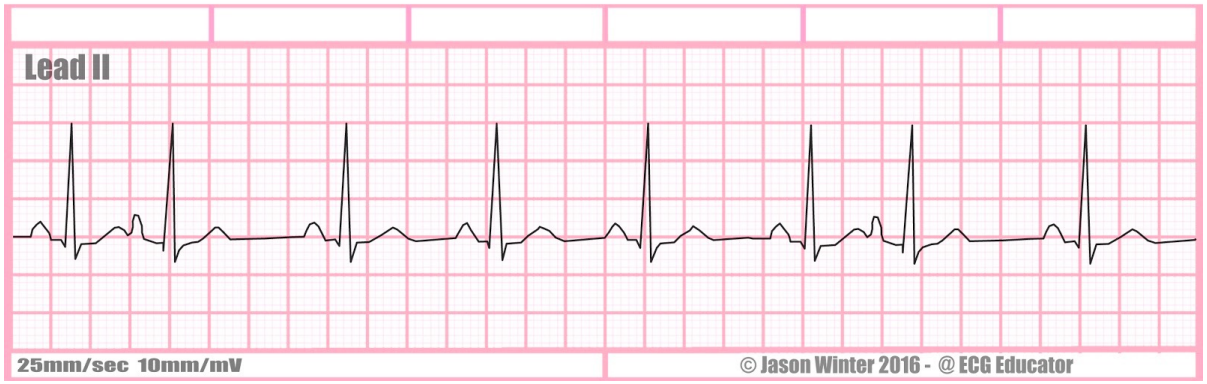
Why is the repolarisation positive?



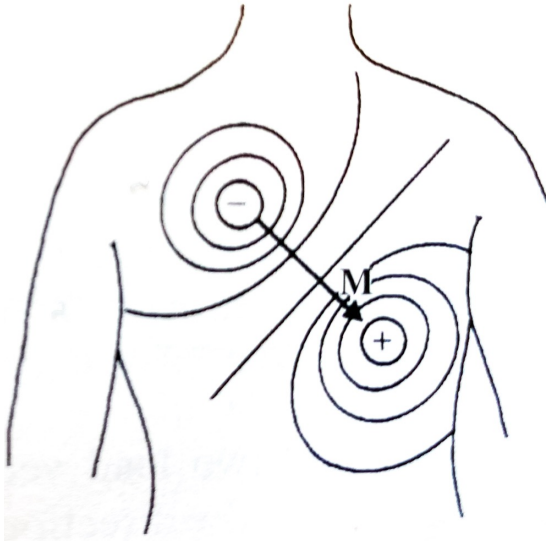
Figur 3:39. Aktionspotentialens uppkomst i hjärtmuskeln.

What can we read from the ECG?



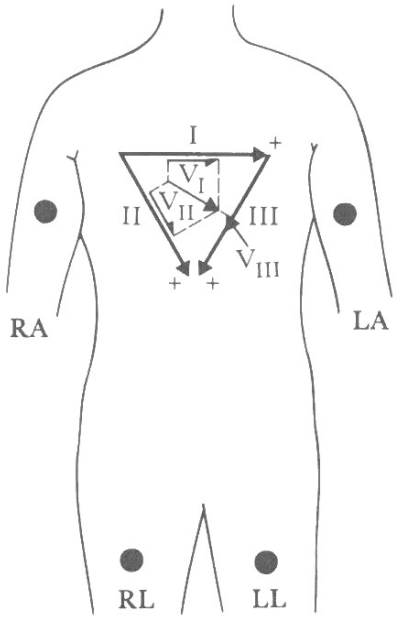


The cardiac dipole vector



- The electrical activity can be represented as a vector quantity = must know location of signals and time dependence of the amplitude
- Simplified model – The heart consists of an electrical dipole from sternum to apex
- Easy to represent quite a complex elctrophysiological entity with a vector from the negative charge to the positive charge, the magnitude is proportional to the amount of charge
- The dipole vector is represented as **M**
- The electrid potentials generated by the heart appear throughout the body and on its surface
- Can be measured with electrodes, trying to minimize the current flow (Why?)

- The Einthoven triangle, placement of ***bipolar*** electrodes. Kirchhof says: I+III=II



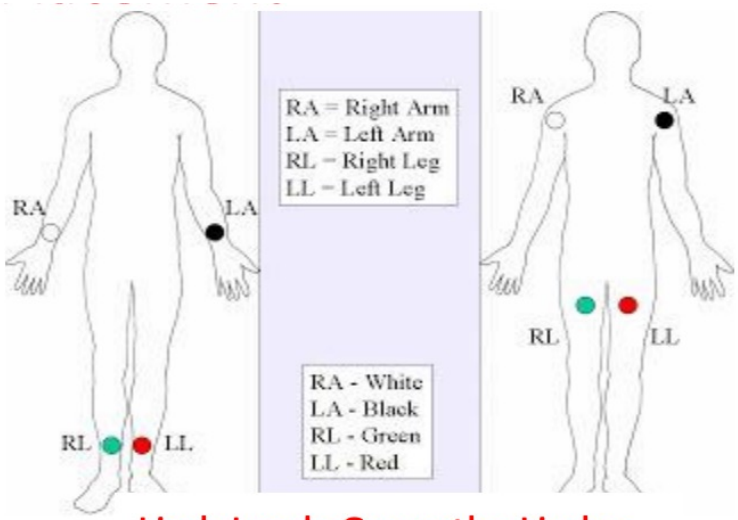
Lead axis is the direction of electrical depolarisation

Figure 6.3 Cardiologists use a standard notation such that the direction of the lead vector for lead I is 0°, that of lead II is 60°, and that of lead III is 120°. An example of a cardiac vector at 30° with its scalar components seen for each lead is shown.

- How can we obtain this signal?

Limb Lead Electrode placement

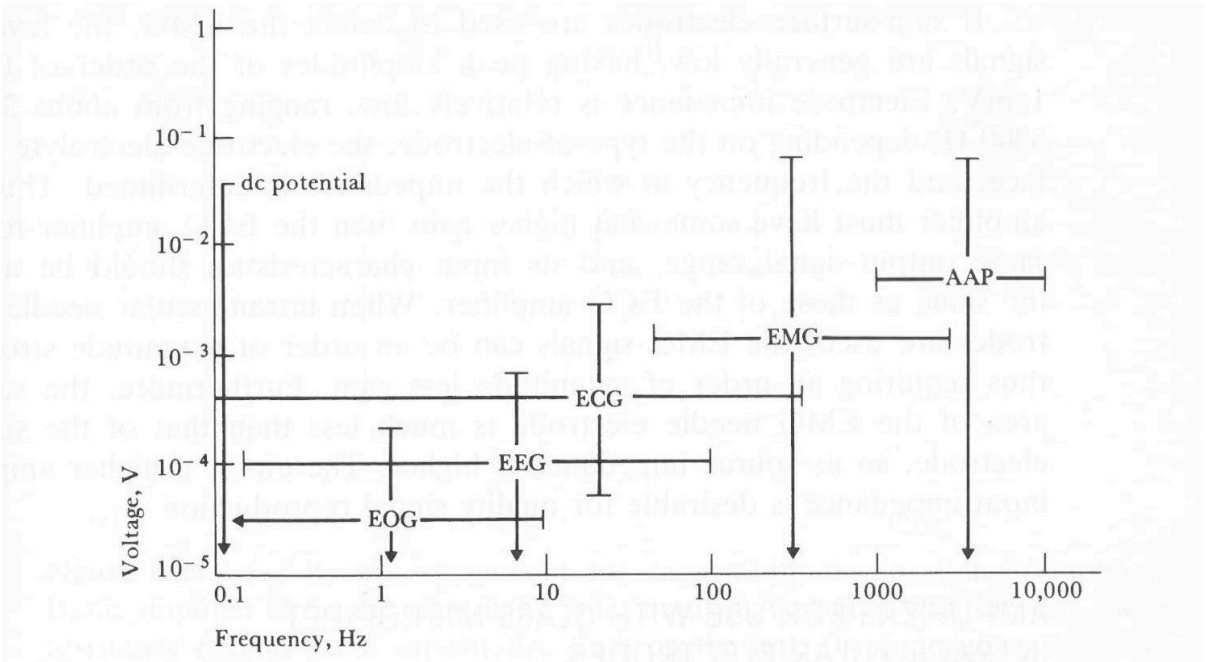
- Preferred site of electrodes is slightly proximal to wrist and ankles
- Can also use upper arms and legs, but must be consistent
- Best over flat, fleshy tissue, avoid muscle and bony areas (why?)



Limb Leads Go on the Limbs

Image: heart.org

- The ECG-signals are very weak



- Wilson central terminal, ***unipolar electrodes***

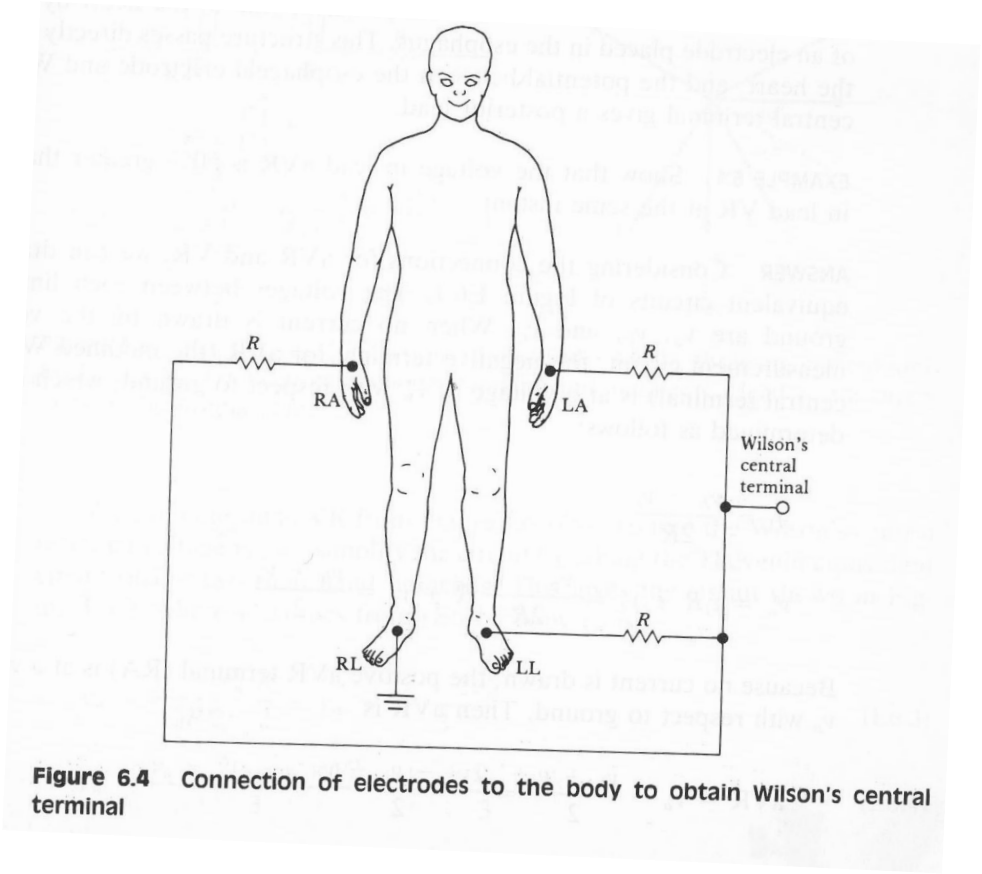


Figure 6.4 Connection of electrodes to the body to obtain Wilson's central terminal

- Still a small, noisy signal. What to do?

- Augmented leads: 50% increased amplitude

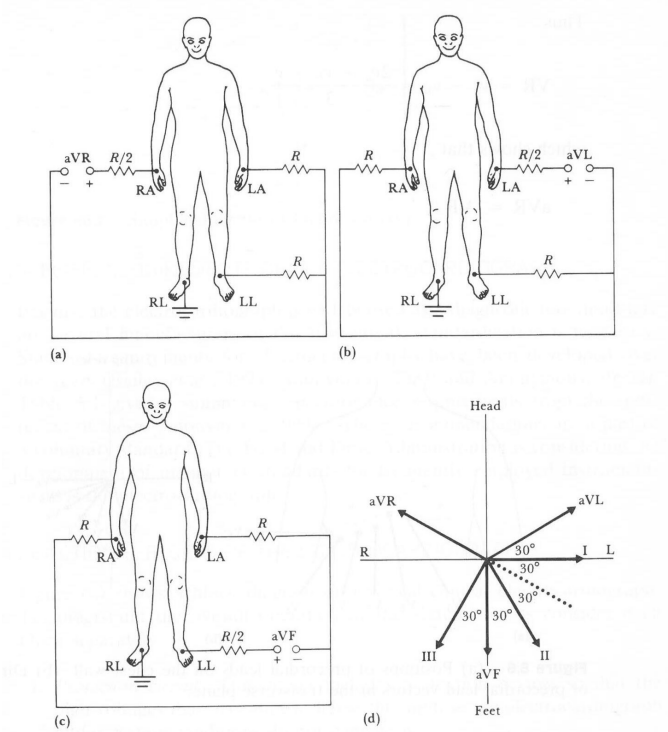
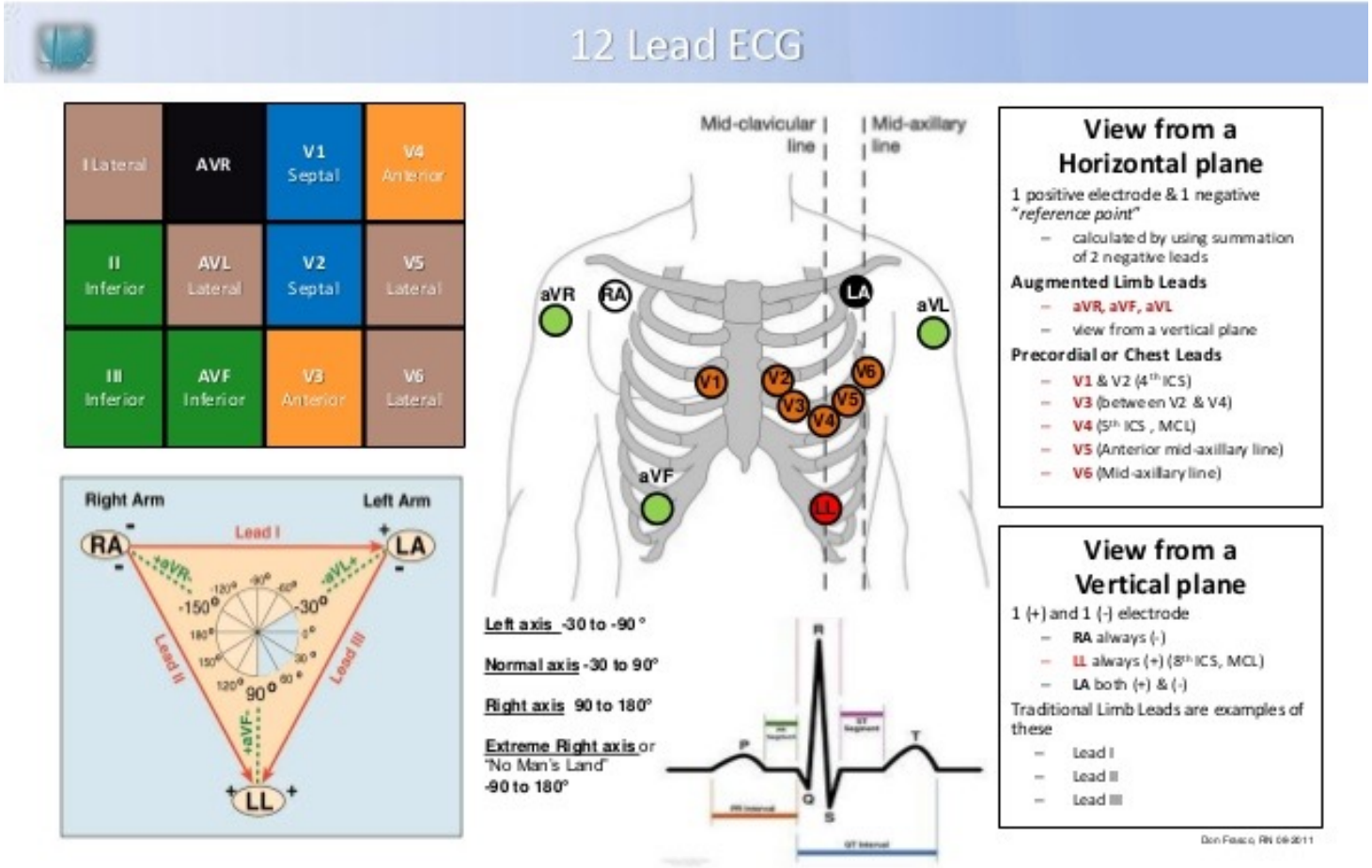


Figure 6.5 (a), (b), (c) Connections of electrodes for the three augmented limb leads. (d) Vector diagram showing standard and augmented lead-vector directions in the frontal plane.

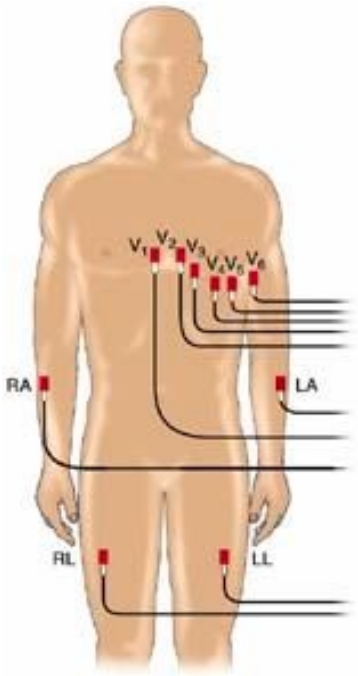
- Still too much noise, what to do?

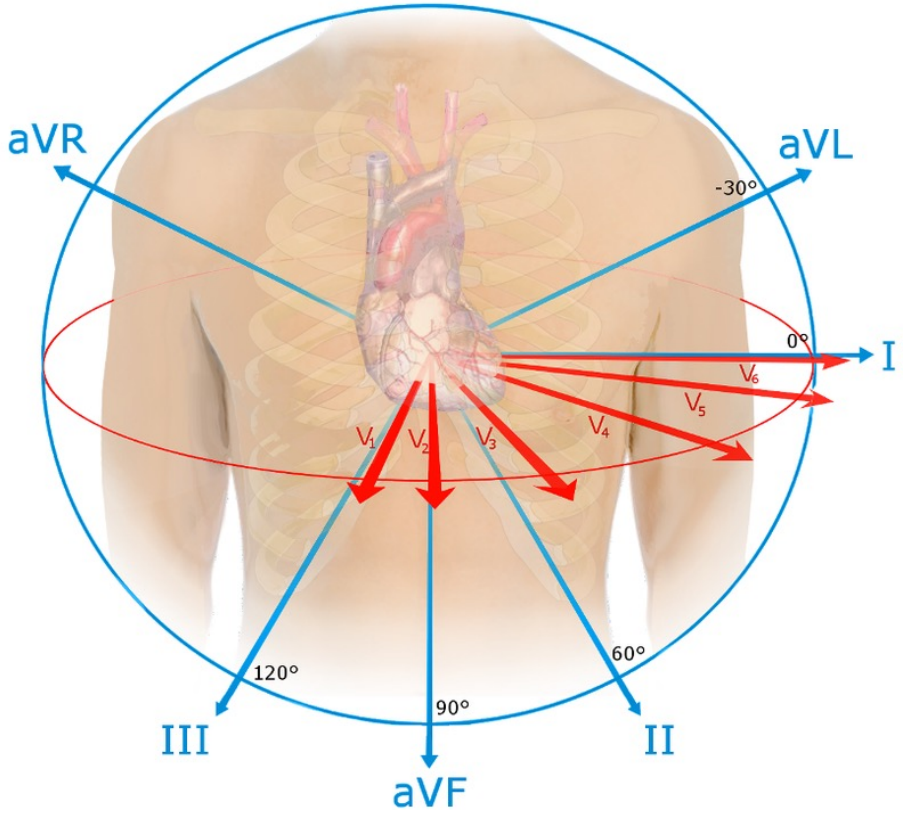
12-lead ECG



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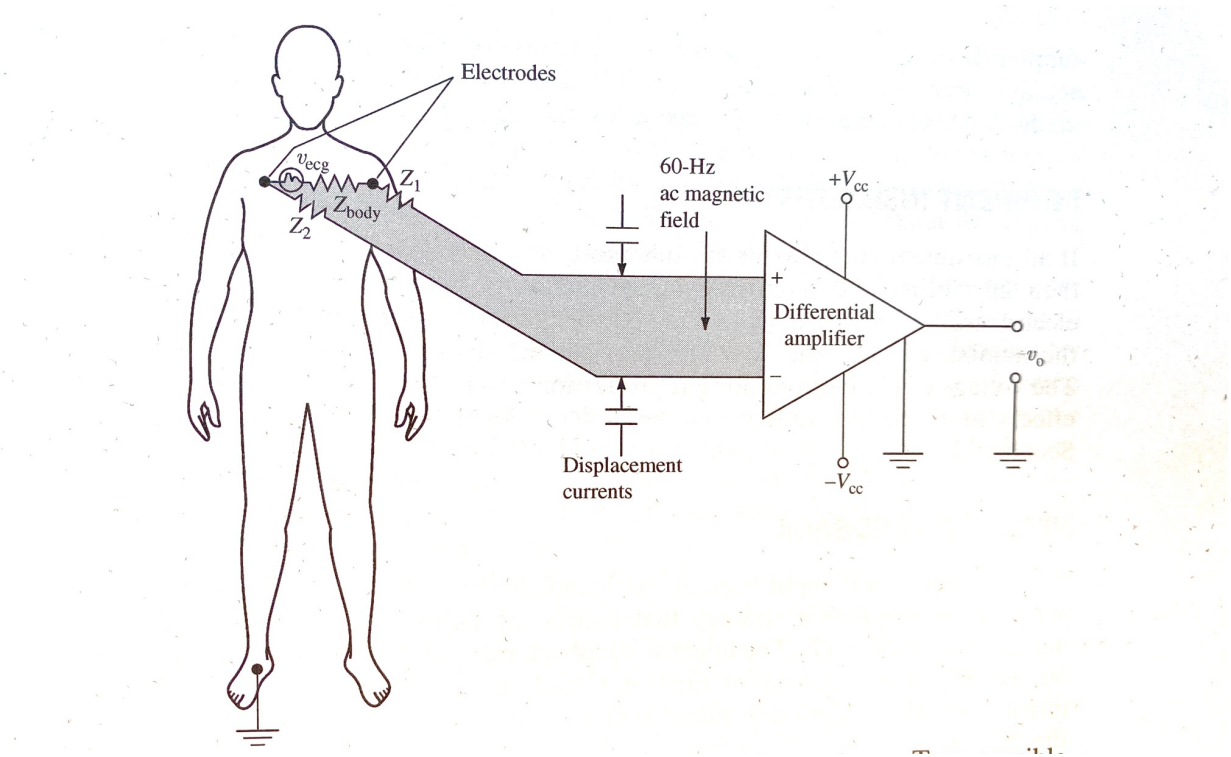
12-lead ECG





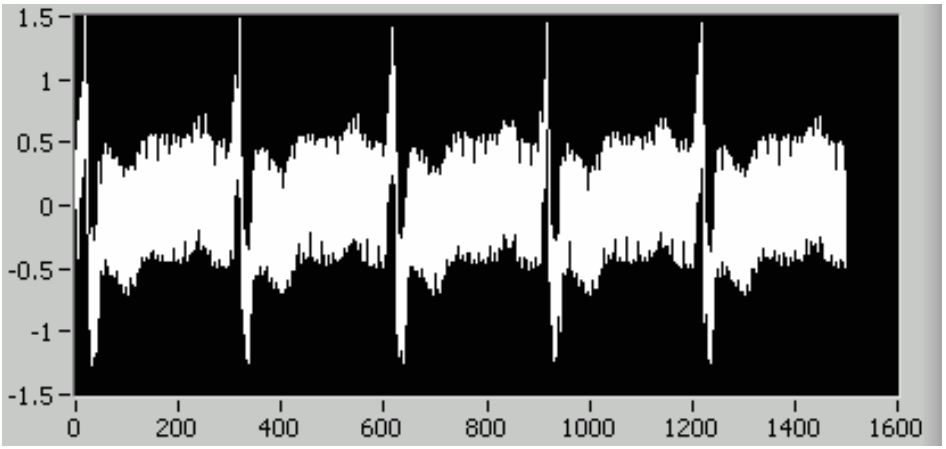
https://en.wikipedia.org/wiki/Electrocardiography#/media/File:Directions_of_EKG_leads.png

Interfering and modyfing inputs



What are the desired, interfering and modyfing inputs?

- The patient is taken into a room for ECG-examination. However, the signal appears to be noisy and difficult to interpret.



- Where does the noise come from?

- Alternative 1, electric field pickup

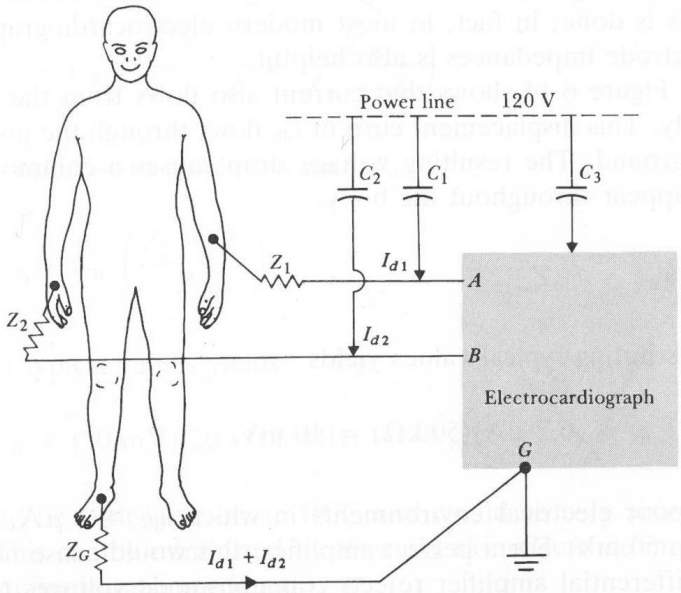


Figure 6.13 A mechanism of electric-field pickup of an electrocardiograph resulting from the power line. Coupling capacitance between the hot side of the power line and lead wires causes current to flow through skin-electrode impedances on its way to ground.

- Alternative 2, magnetic field pickup

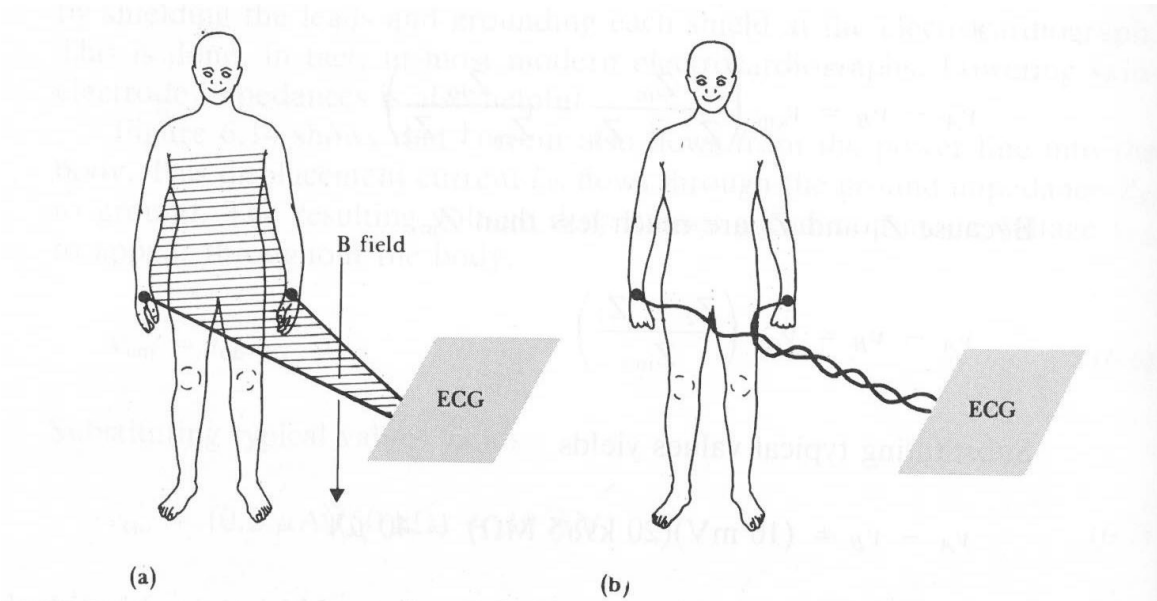


Figure 6.15 Magnetic-field pickup by the electrocardiograph (a) Lead wires for lead I make a closed loop (shaded area) when patient and electrocardiograph are considered in the circuit. The change in magnetic field passing through this area induces a current in the loop. (b) This effect can be minimized by twisting the lead wires together and keeping them close to the body in order to subtend a much smaller area.

- Alternative 3, common mode voltage

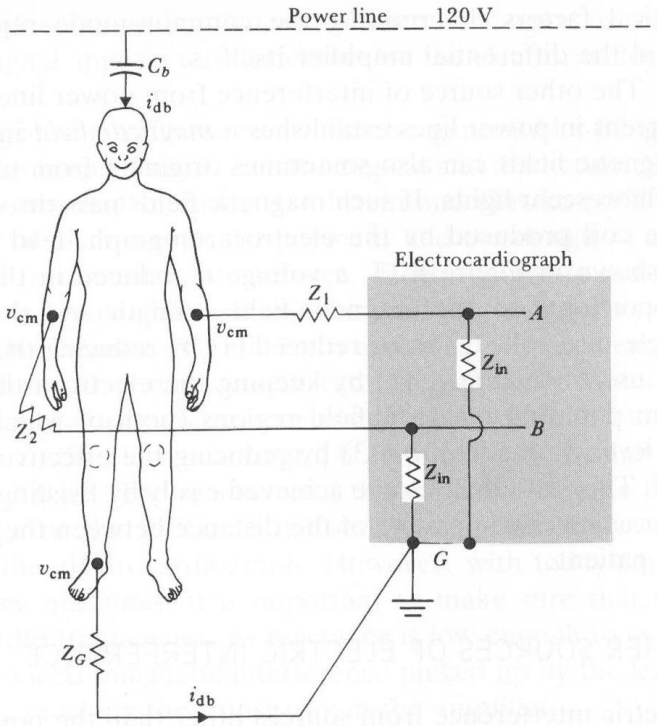
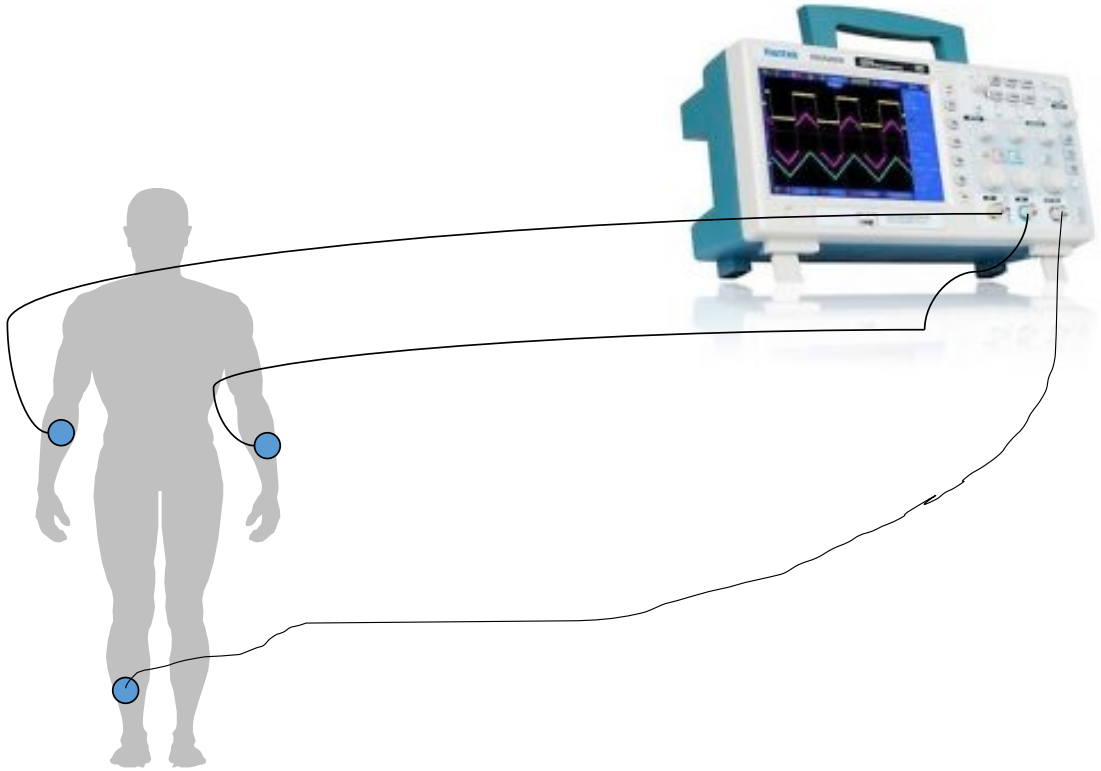


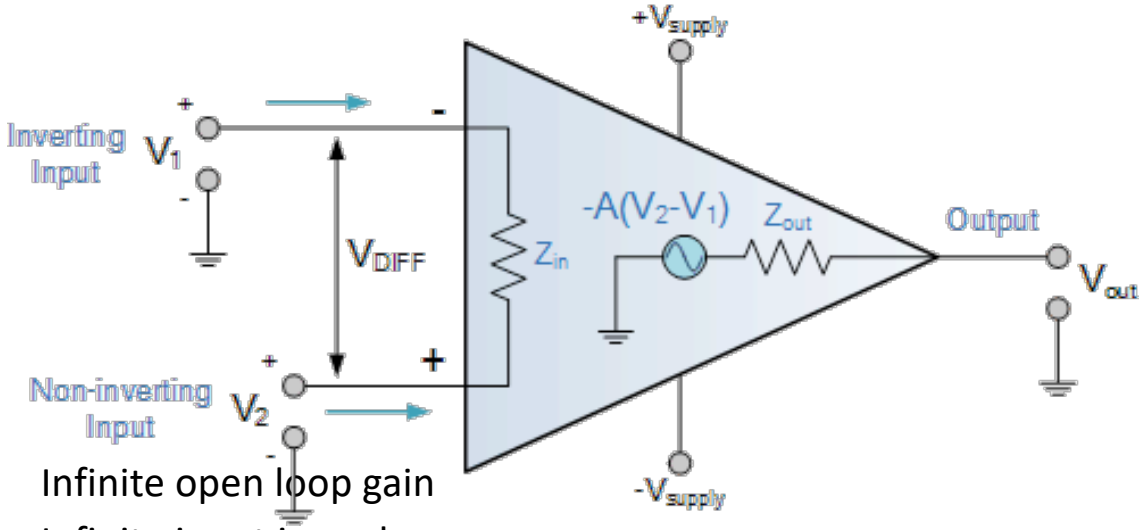
Figure 6.14 Current flows from the power line through the body and ground impedance, thus creating a common-mode voltage everywhere on the body. Z_{in} is not only resistive but, as a result of RF bypass capacitors at the amplifier input, has a reactive component as well.

- Converting ion-current in the body to electronic current outside the body through the electrodes



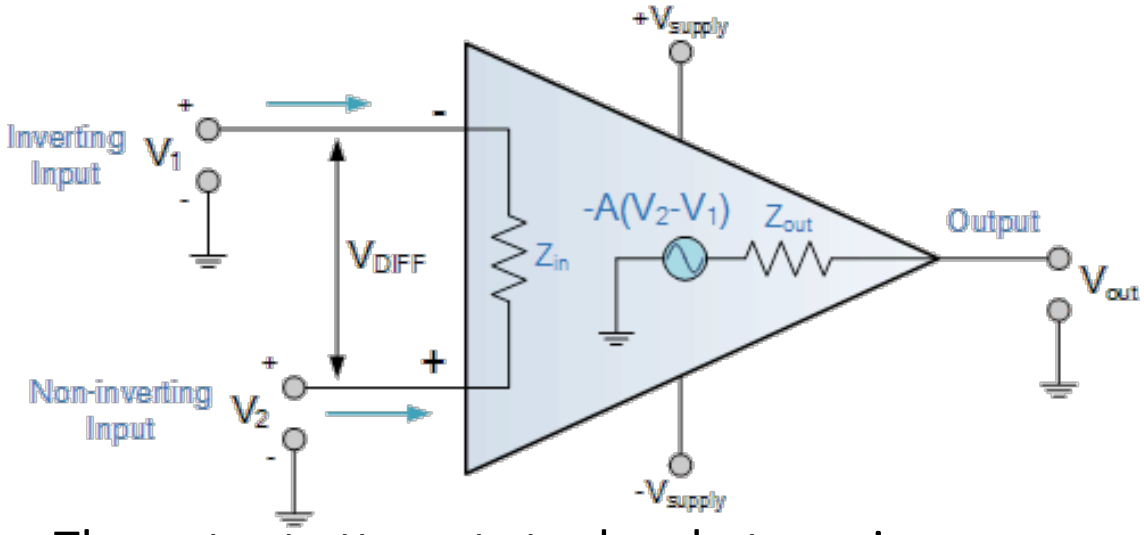
- Three leads into one signal?

- Introducing the ideal operational amplifier



1. Infinite open loop gain
2. Infinite input impedance
3. Zero output impedance
4. Zero offset voltage
5. Infinite bandwith

- The ideal operational amplifier can be summed up in two golden rules:



1. The output attempts to do whatever is necessary to make the voltage difference between the inputs zero
2. The input draws no current

www.dummies.com

- How to build an ECG-amplifier

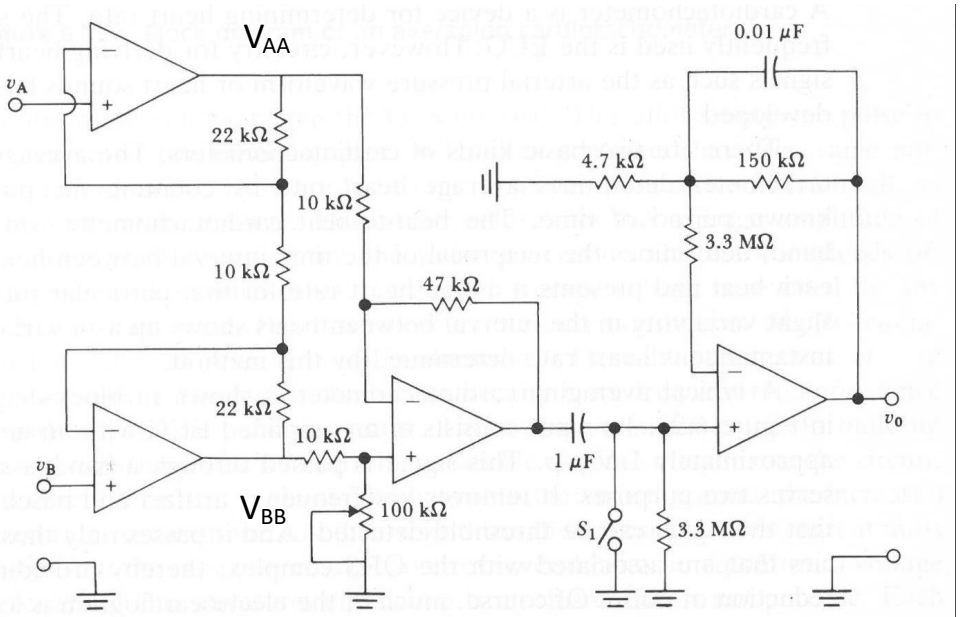


Figure 6.22 This ECG amplifier has a gain of 25 in the dc-coupled stages. The high-pass filter feeds a noninverting-amplifier stage that has a gain of 32. The total gain is 25 × 32 = 800. When μA 776 op amps were used, the circuit was found to have a CMRR of 86 dB at 100 Hz and a noise level of 40 mV peak to peak at the output. The frequency response was 0.04–150 Hz for ±3 dB and

- Faraday cage is the ultimate solution

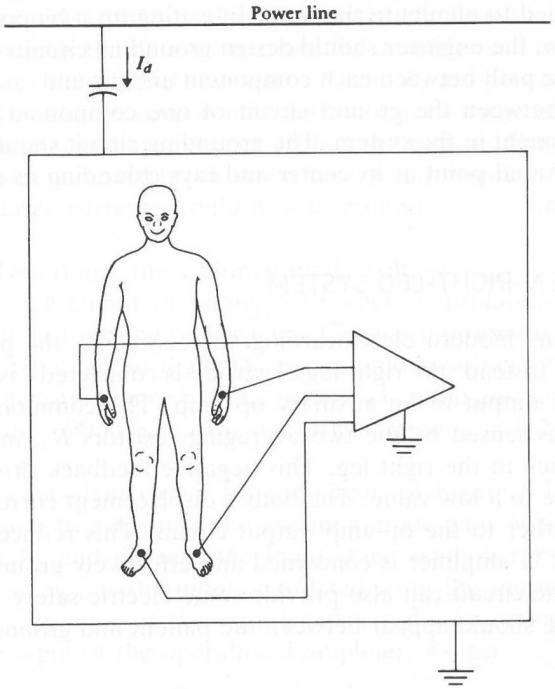
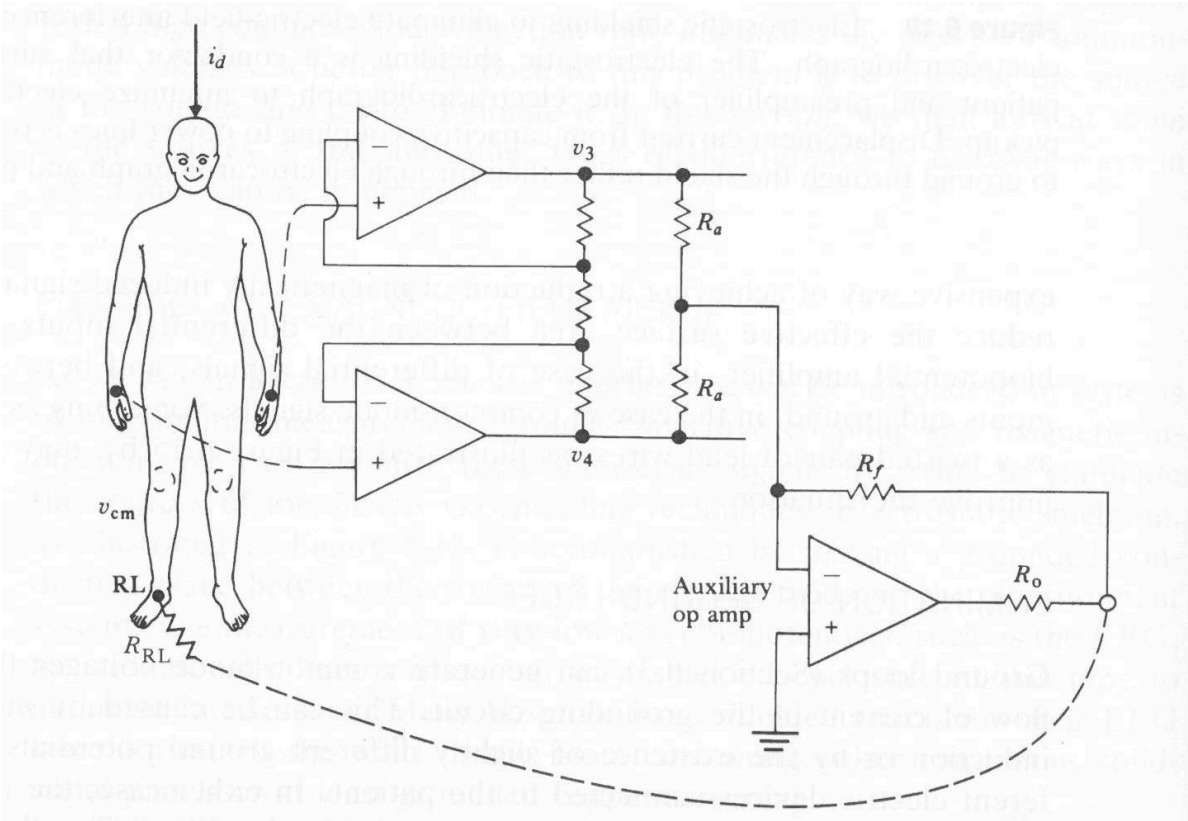


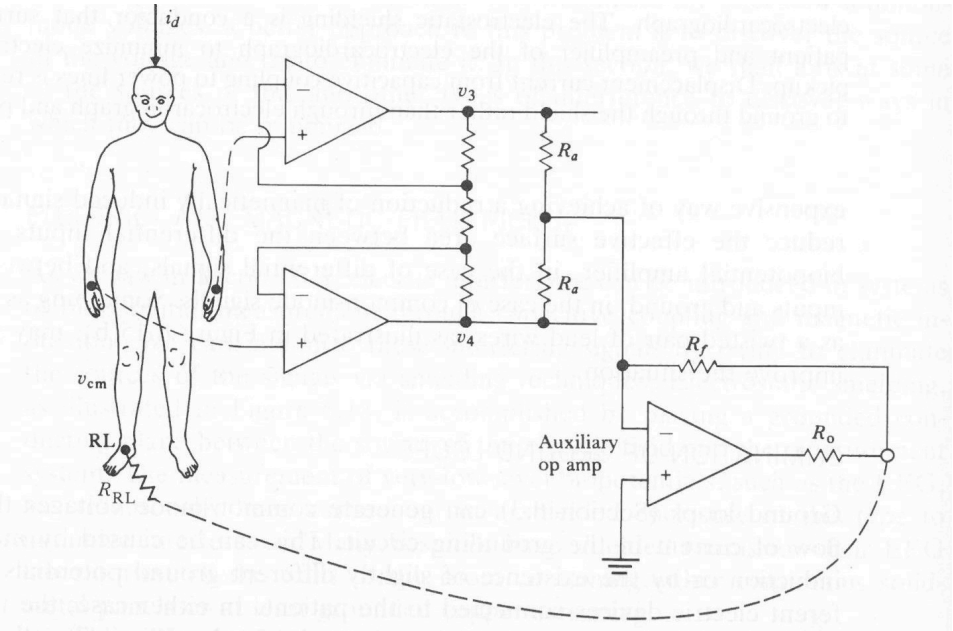
Figure 6.18 Electrostatic shielding to eliminate electric-field interference on an electrocardiograph. The electrostatic shielding is a conductor that surrounds patient and preamplifier of the electrocardiograph to minimize electrostatic pickup. Displacement current from capacitive coupling to power lines is returned to ground through the shield rather than through electrocardiograph and patient.

- Practical solution?

- ***Driven right leg*** is the practical solution



Exercise



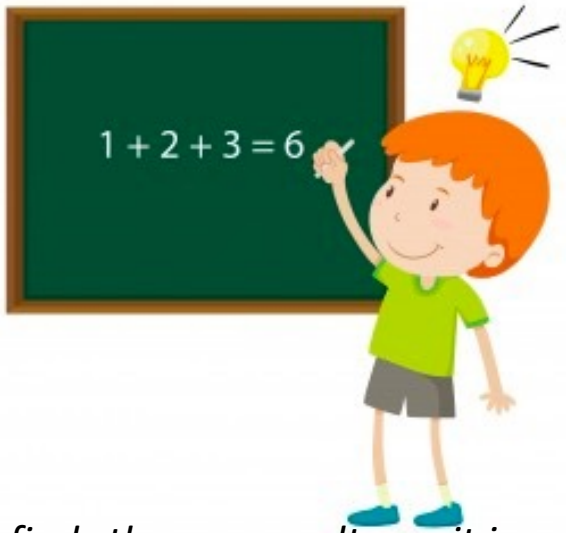
Based on what you learned from the ECG-amplifier:

a. How does the driven-right-leg work?
b. Is it a built-in electrical safety system in driven right leg?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answer



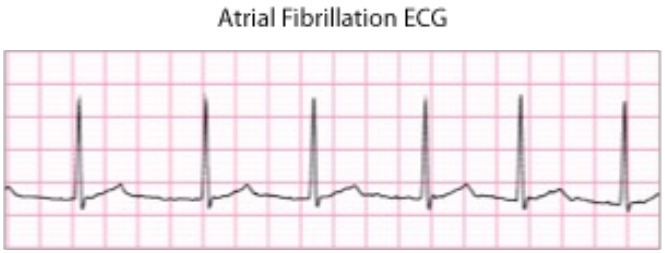
a. Amplifiers avoid loading of the patient, finds the mean voltage, it is inverted, amplified and fed back to the right leg

b. If excessive currents should appear, the op. amps will saturize and then ungrounds the patient because the amplifier can no longer drive the right leg.

Case 2

- Driven right leg + ECG amplifier gives us this ECG signal (the right, a regular sinus to the left)
  - No P-waves and irregular ventricular response



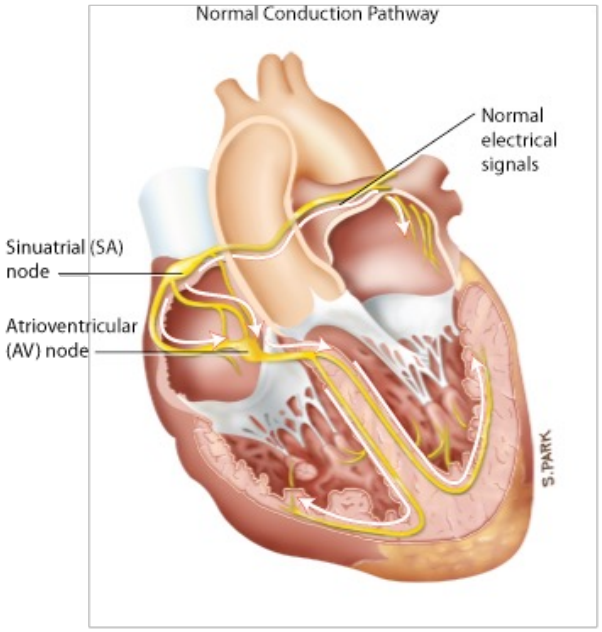


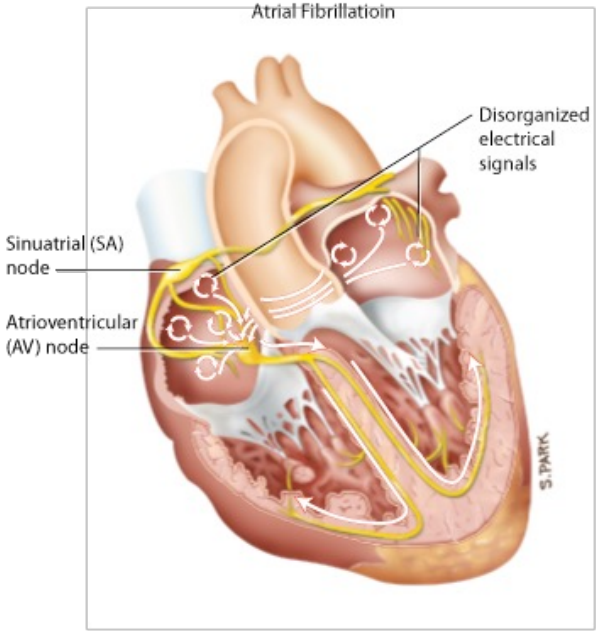
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- What is the diagnosis?

Case 2

- Answer: Atrial fibrillation (Birkebeiner disease)

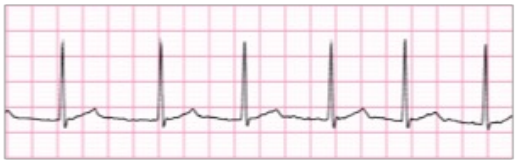




Normal ECG



Atrial Fibrillation ECG



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- Caused of?

Case 2

- Answer: Because of the loss of atrial contraction, the atrial fibrillation has caused a pulmonary edema.

  -This is most probably caused by a rheumatic heart disease

  - Atrial fibrillation have an increasing incidence with age, affecting 10% of patients older than 75 years of age

  - Rapid atrial depolarization, often at rates exceeding 300-400 bpm

  - The most common arrhythmia for which patients seek doctor

Toy, Patlan, Cruse, Faustinella, Case Files Internal medicine, McGrawhill

- Is it dangerous?

Case 2

- Answer: Yes
  - It may trigger a rapid ventricular rate leading to myocardial ischemia or heart failure
  - Atrial fibrillation is a common cause of stroke, due to thrombus formation in the noncontractile atria

The two most common causes are ***hypertension*** and ***coronary atherosclerosis***

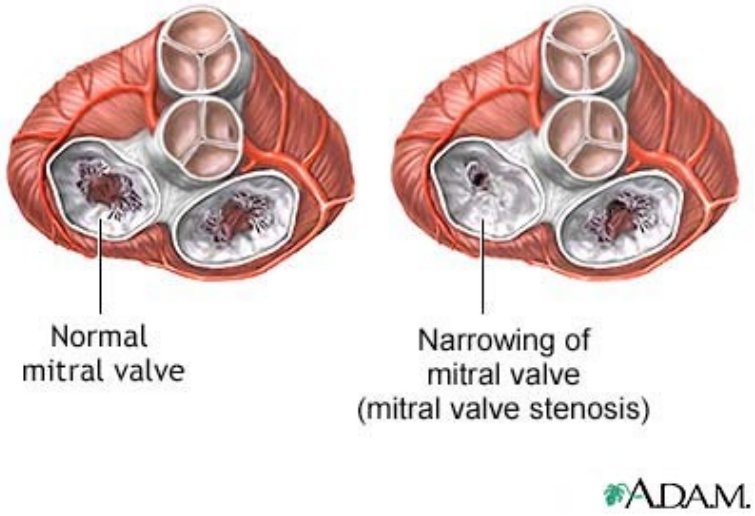
If patient is hemodynamically unstable, urgent cardioversion is indicated. Not all patients can be cardioverted, and the longer the fibrillation, the more likely the patient is to stay there because of electrical remodeling of the heart.

Toy, Patlan, Cruse, Faustinella, Case Files Internal medicine, McGrawhill

- What is rheumatic heart disease?

Case 2

- In this case, the cause of the patient's atrial fibrillation seems to be mitral stenosis, a late sequela of acute rheumatic fever



Toy, Patlan, Cruse, Faustinella, Case Files Internal medicine, McGrawhill

www.healthcentral.com

- Could this be diagnosed by other means?

Case 2

- Yes, by a stethoscope. A loud S1 and an opening snap following S2 with a low-pitched diastolic rumble.
- Yes by ultrasound
- Yes by MRI
- Yes by CT

More about this later in the course



Amazon.com

- And the prognosis?

Case 2

- Very good if converted properly by surgery or medications



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