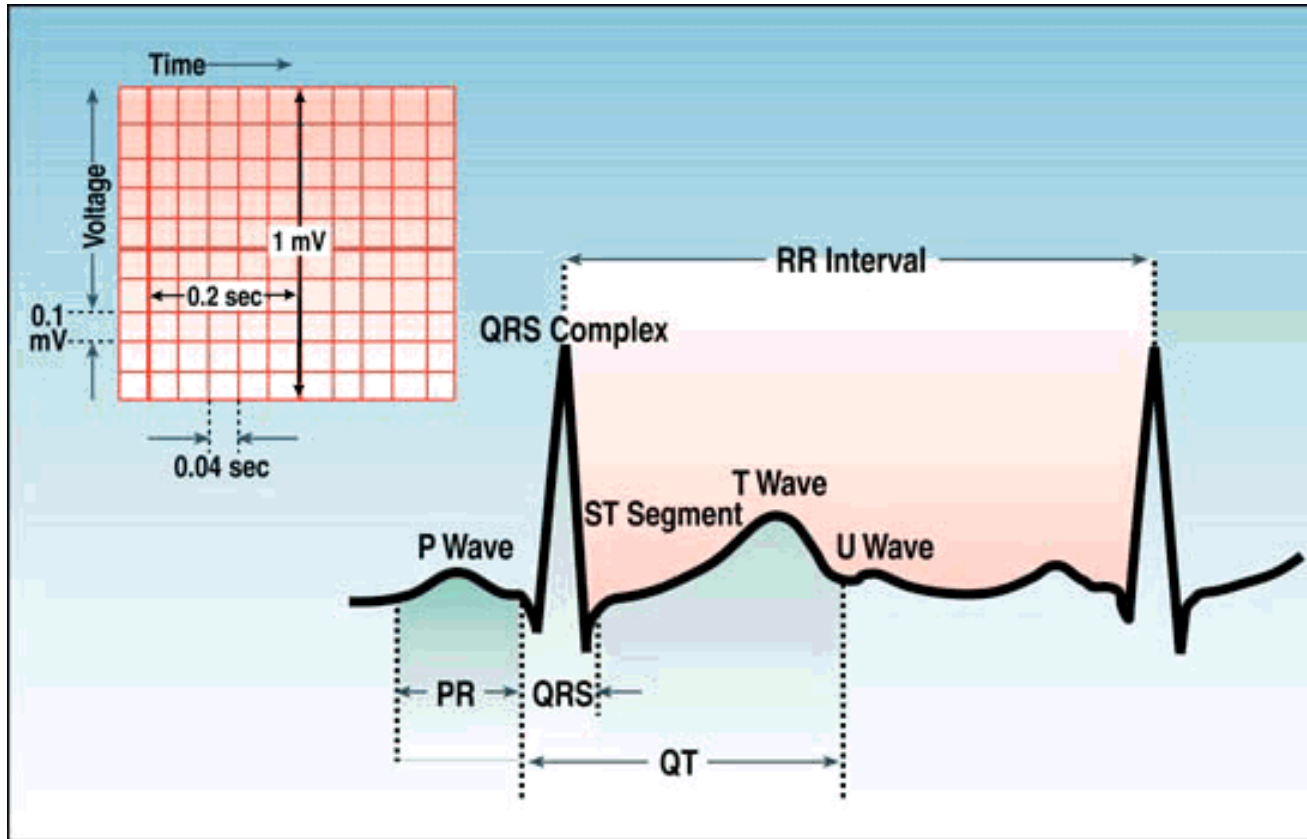


THE ELECTROCARDIOGRAM (ECG)

Preparation for RWM Lab Experiment

The first ECG was measured by Augustus Désiré Waller in 1887 using Lippmann's *capillary electrometer*.



Recorded ECG: http://www.youtube.com/watch_popup?v=Q0JMfIVaDUE&vq=large

Save money with the RWM ECG machine... http://www.med-electronics.com/PageWriter_Trim_II_ECG_p/1934.htm

What is an ECG (or EKG)?

- An Electrocardiograph or Electrocardiogram (ECG), or Elektrokardiogramm (EKG – German spelling) is a graphical record of the **electrical activity of the heart** as measured externally from skin-contact electrodes placed on the body.
- The ECG is considered a very powerful diagnostic tool by Cardiologists (medical doctors specializing in the human heart).
- It identifies a time sequence of the contractions of the left and right chambers of the heart – the mechanisms by which blood is circulated through the body.



DO try this at home, kids

We are going to **build a fully-operational 3-wire ECG measurement instrument using a differential amplifier**. The three-wire connection is the simplest that will yield a usable trace (not just a heart rate). The resulting ECG will reveal all the electrical activity of the heart, only lacking the benefit of ECG signals measured between other body contact points. A full ECG diagnosis involves the connection of 12 electrodes across the chest and on the extremities. We will only be connecting electrodes to the arms and ankle.

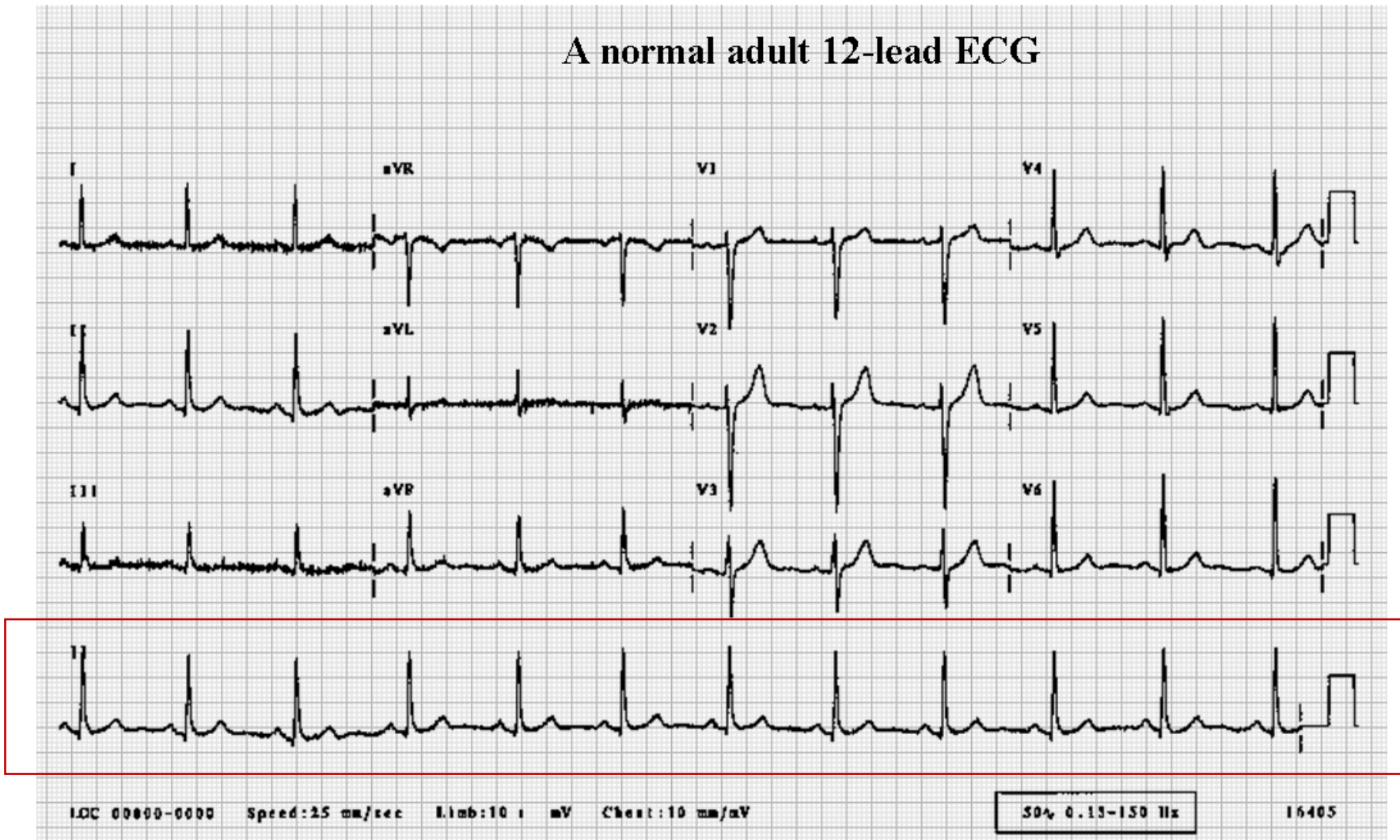
WE ARE NOT MEDICAL DOCTORS, and neither are you. I'll talk a little about how the heart works and how to correlate specific wave components of the ECG with heart contraction events. But **please don't attempt to interpret anything other than possibly your heart rate (beats per minute) from your ECG**. Experts on ECG interpretation form an entire \$pecialization.

If you would like to learn more about ECG interpretation on your own, you can:

1. Go to medical school.
2. Check out any of hundreds of web sites, textbooks, and even several YouTube videos on interpretation of the ECG, e.g.,
<http://www.youtube.com/watch?v=HG1hD12Dip4>

Our 3-wire measurement will be similar to the plot at the bottom of this partial printout of a 12-wire ECG ensemble. From <http://www.ecglibrary.com/norm.html> :

A normal adult 12-lead ECG



Safety Issues - Interfacing Electronics to the Human Body

“A 60-Hz current of barely 10 uA flowing through the heart has the potential of causing permanent damage or even death.” From *Design and Development of Medical Electronic Instrumentation*, by David Prutchi and Michael Norris. Wiley, 2005. p. 97.

Medical instrumentation safety standards are regulated in the USA by the Association for Advancement of Medical Instrumentation (AAMI), American National Standards Institutes (ANSI), and Underwriters Laboratories (UL). AAMI standards have been adopted as official practice by the American Medical Association. Other standards apply depending on the country in which the device is deployed: UL standard 2601-1 (USA), IEC-601 (International), EN-60601 (EU), CAN/CSA-C22.2 601.1 (Canada), AS3200.1 (Australia), and NZS6150 (New Zealand).

We are performing an AAMI Type B connection to the body, since we are potentially connecting a direct ground to the patient (you). This is considered risky because of the possibility of a ground loop if any other Type B medical instrumentation is connected that may have a different ground connection. Our ground connection is established through the 5 VDC USB power supply in your notebook computer, which may (but usually doesn't) connect to the building wiring ground via the power brick's wall plug ground prong. To fully comply with AAMI recommendations:

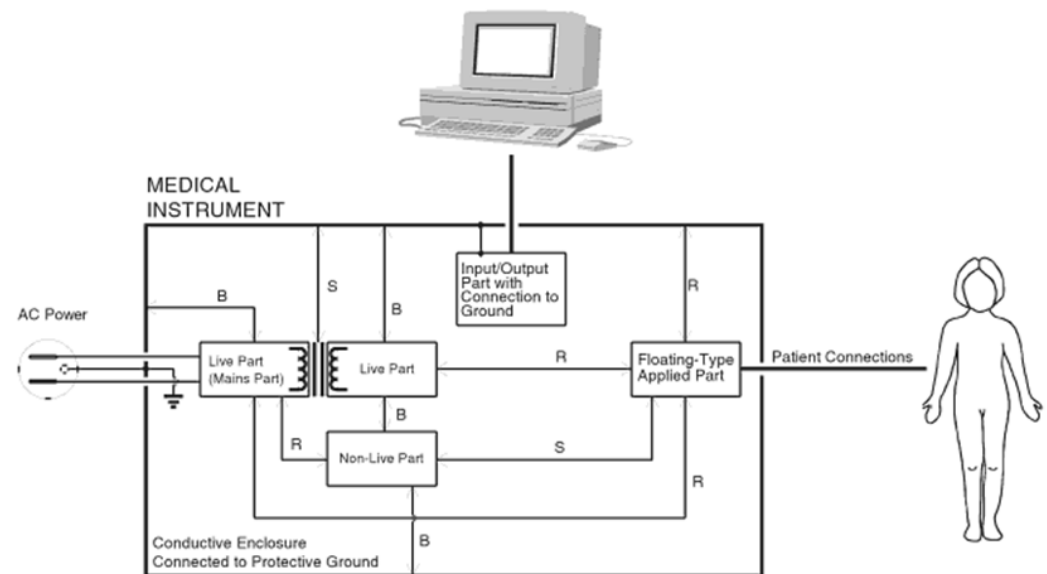
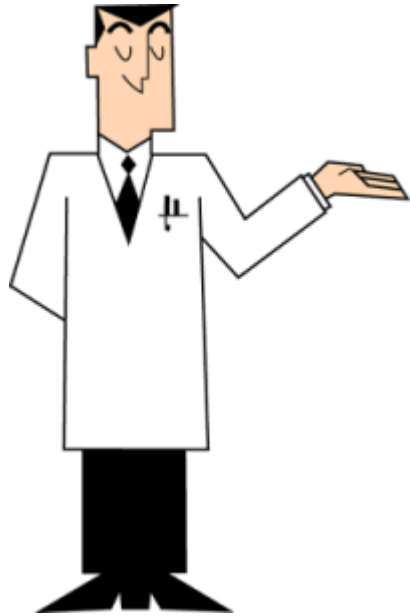


Figure 3.1 Some of the requirements for insulation between the parts of a medical instrument. Insulation types: B, basic; S, supplementary; R, reinforced.



RWM Instructors Recommend:

1. Don't connect yourself to any other AC-powered instrumentation while you are doing this experiment. Do not connect yourself to ground by holding onto an earth connection such as a water fixture.
2. Unplug the power brick from your notebook computer, and run the notebook on its batteries during the ECG experiment. This converts the connection to a Type BF (fully floating) connection.

About Privacy...

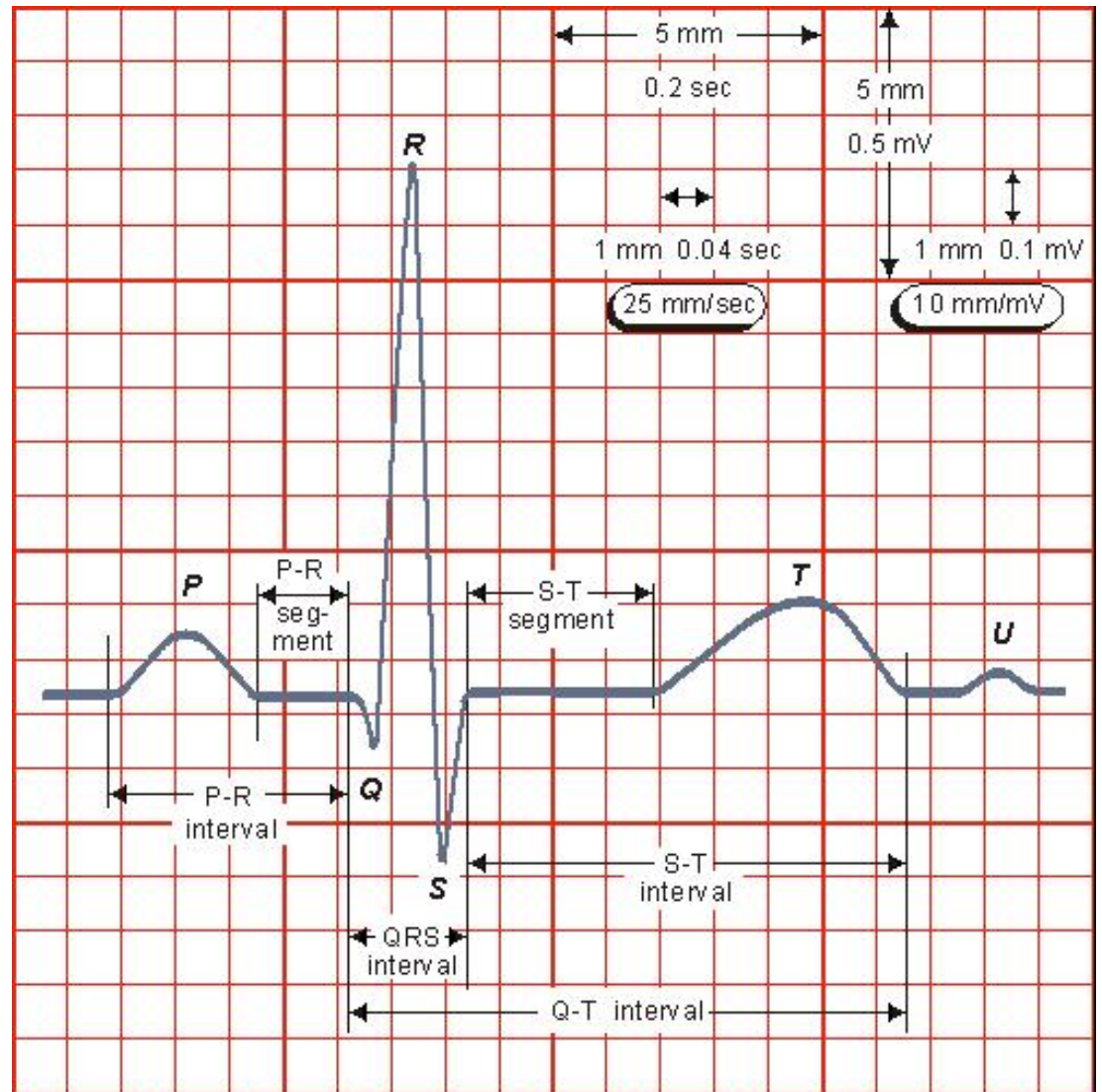
Finally, if you are AT ALL concerned about submitting your personal ECG plot in your lab report, YOU DO NOT HAVE TO DO SO. This could be construed as medical information protected under Federal HIPAA privacy laws, i.e., <http://www.hhs.gov/ocr/privacy/hipaa/understanding/index.html> . You may alternatively borrow one of the instructors who will serve as your patient (as long as you don't post our ECGs on the web).



The Heart Conduction Cycle

The human heart is an amazing bio-electrical device. The source(s) of the electrical signals that activate and sequence the heart muscles are two redundant internal “pacemakers” referred to as the primary and secondary Sinus Nodes.

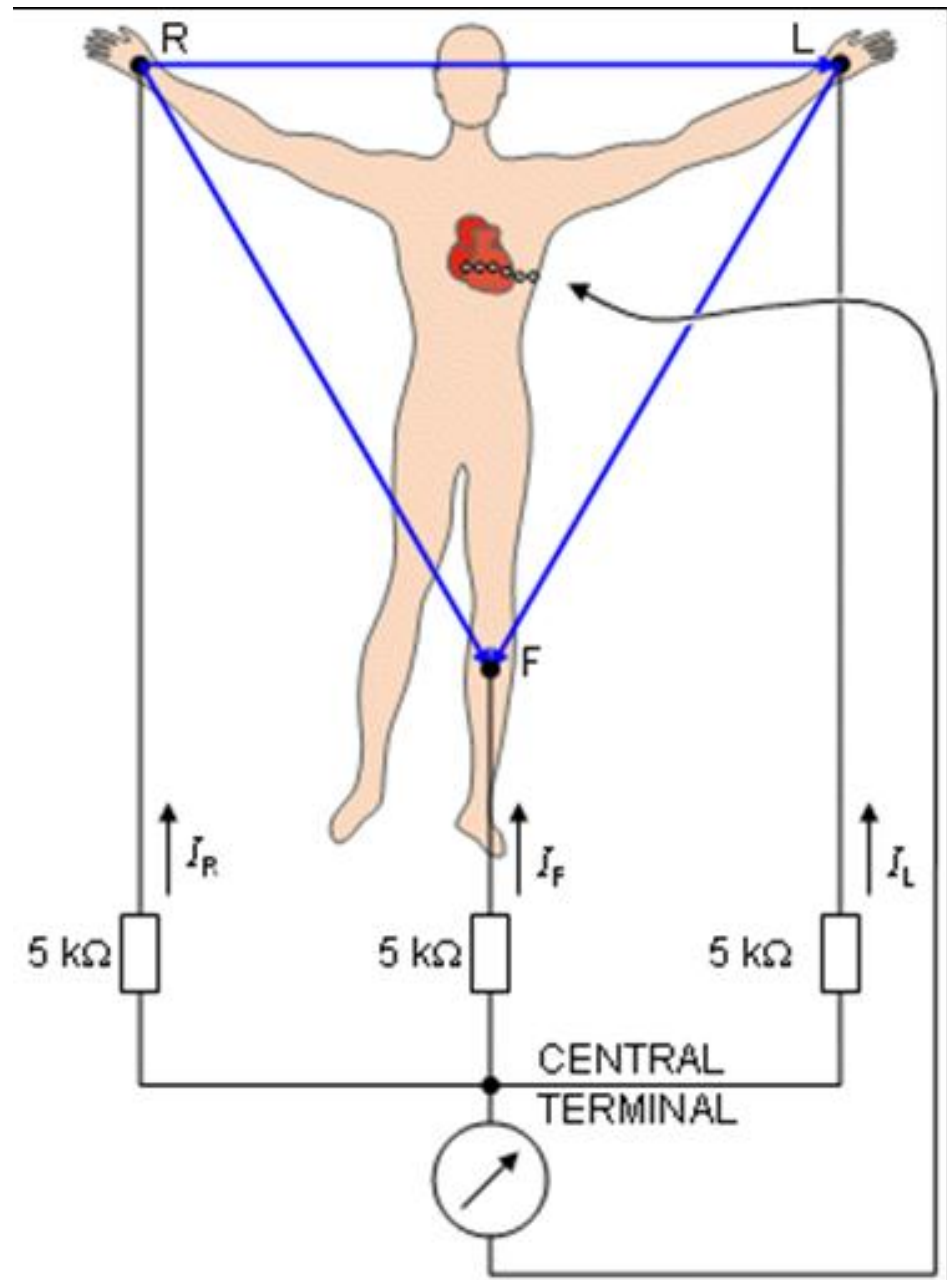
These are signal generators that produce a periodic sequence of electrical pulses (in the mV range) that cause the four chambers of the heart to contract in the proper order, pumping blood through the circulatory system.



Where to make a 3-wire ECG measurement?

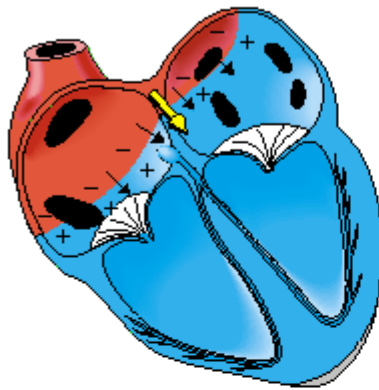
From <http://www.bem.fi/book/index.htm>

The “Wilson central terminal (CT)”.
We will measure the potential between points R and L, both referenced to L, using a differential amplifier.



The generation of the ECG signal as measured in limb (Einthoven) leads:

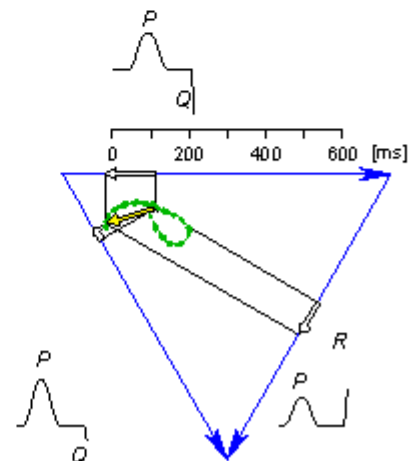
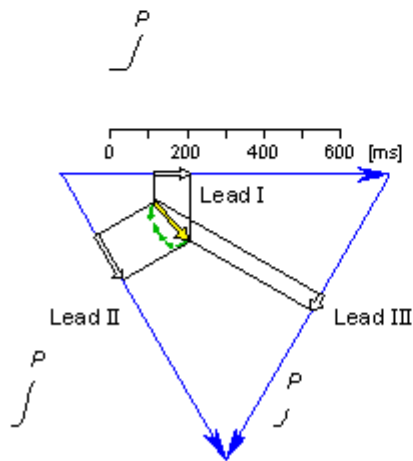
ATRIAL
DEPOLARIZATION
80 ms



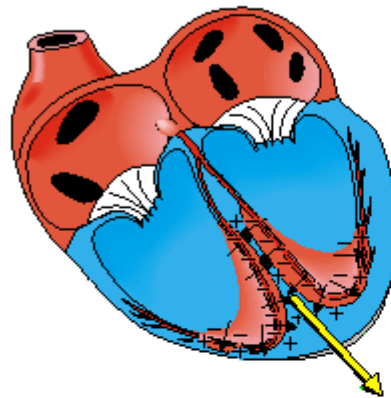
SEPTAL
DEPOLARIZATION
220 ms



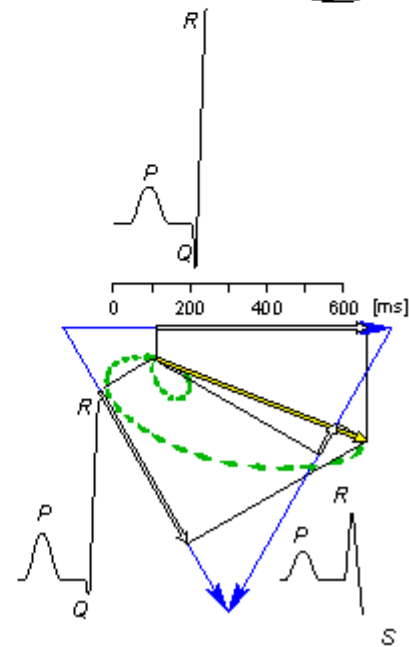
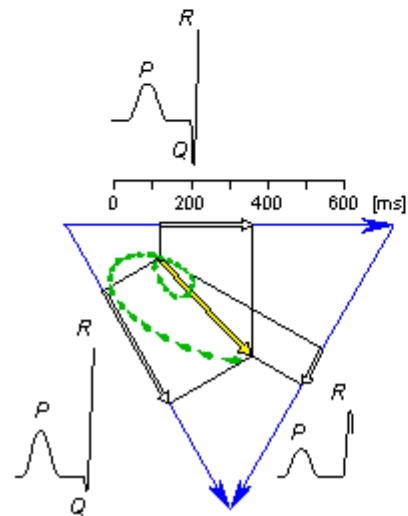
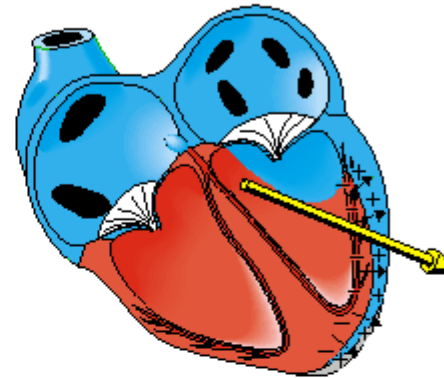
The sequence of heart contraction phases and the parts of the ECG that they correspond to.



APICAL
DEPOLARIZATION
230 ms

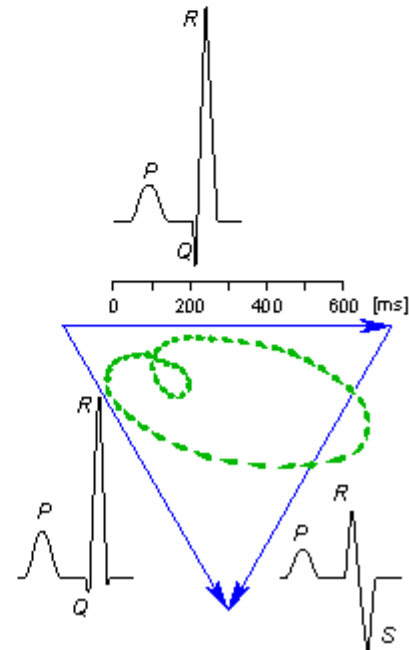
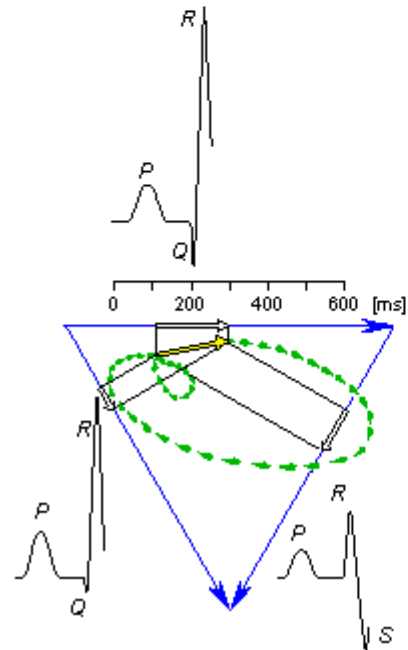
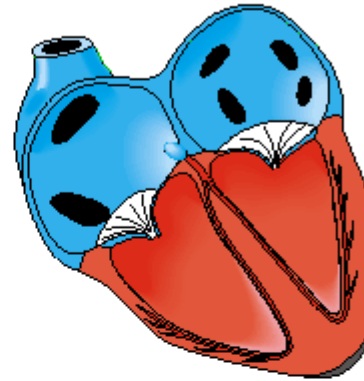
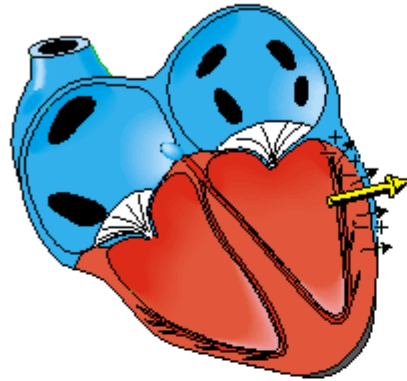


LEFT VENTRICULAR
DEPOLARIZATION
240 ms



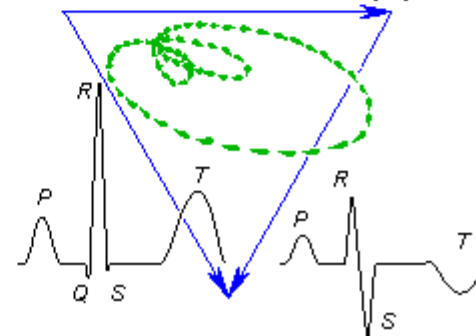
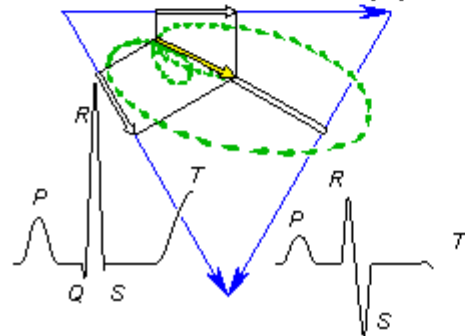
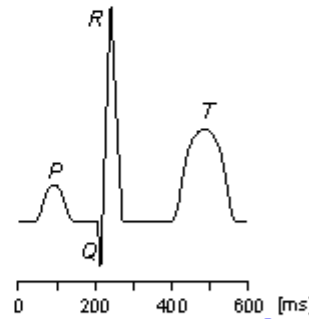
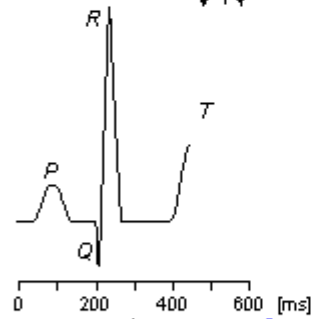
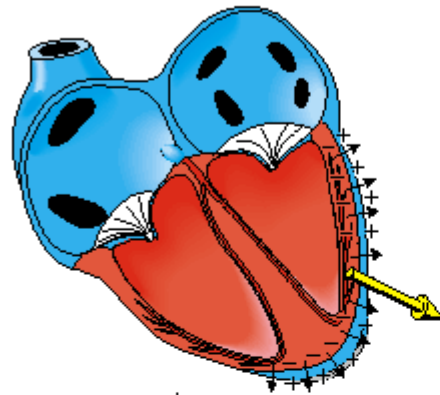
LATE LEFT VENTRICULAR
DEPOLARIZATION
250 ms

VENTRICLES
DEPOLARIZED
350 ms

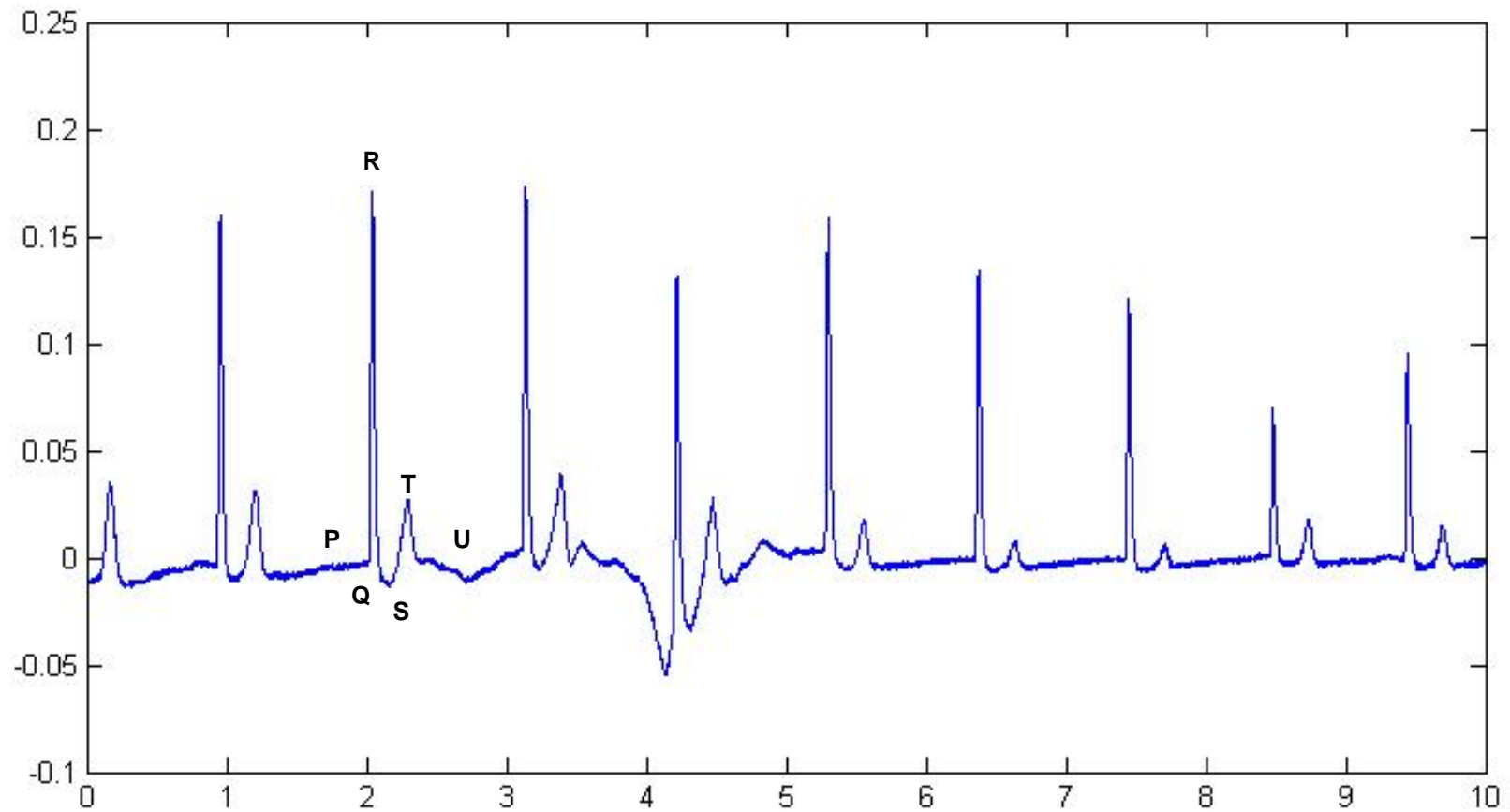


VENTRICULAR
REPOLARIZATION
450 ms

VENTRICLES
REPOLARIZED
600 ms



What will our experimental ECGs look like?

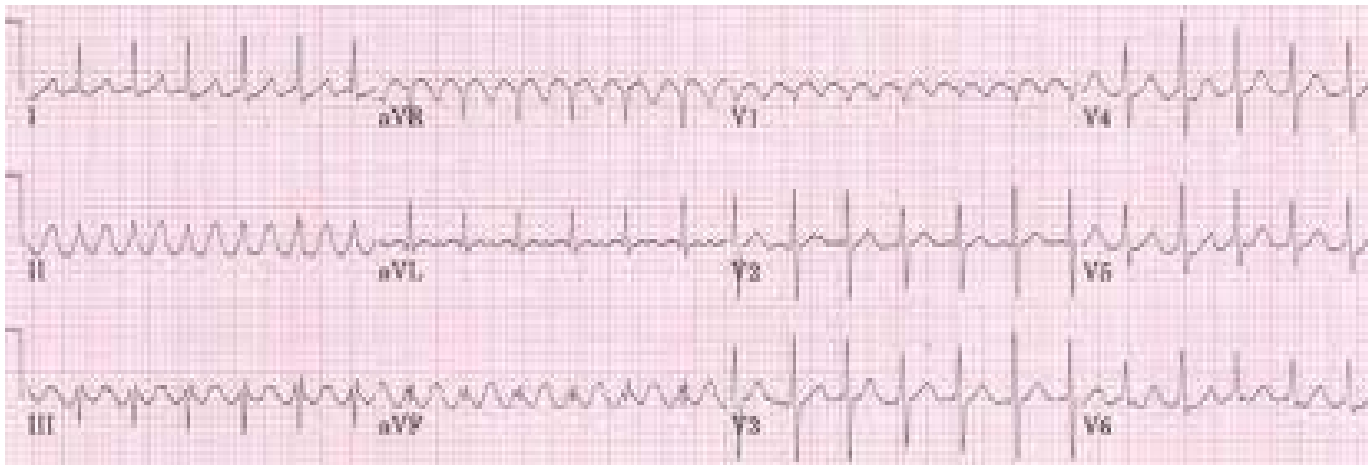


What happens on ER[©] when a patient “codes” and they get out the paddles?



Portable Cardiac Defibrillator

Atrial Fibrillation:



Video of ECG during Cardiac Arrest:

<http://www.youtube.com/watch?v=XV11kplLoxw&feature=related>

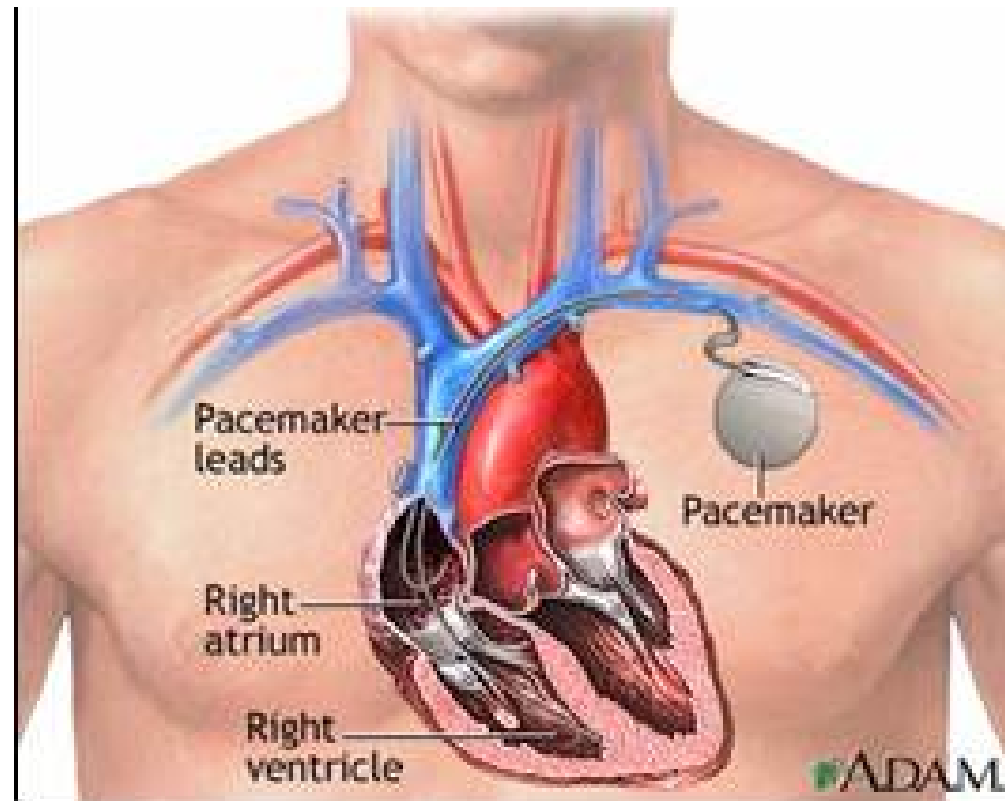
During defibrillation:

http://www.youtube.com/watch?v=ReJo4aclOw8&feature=feedrec_grec_index

What medical device can be implanted to replace the function of the heart's internal pacemakers?

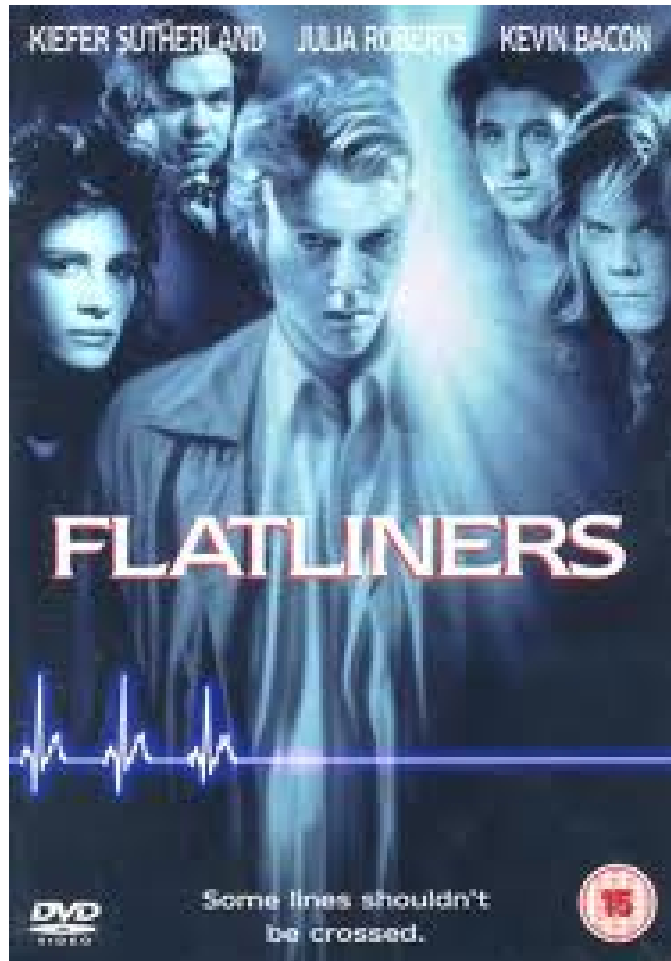


St. Jude Medical Corp. SR "Adaptive Rate" monopolar pacemaker. http://en.wikipedia.org/wiki/St._Jude_Medical



In 1958, Arne Larsson (1915-2001) became the first to receive an implantable pacemaker. He had a total of 26 devices during his life.

What famous actress played a medical student in a film about ECGs in 1990?



For Further Study: Characteristics of the ECG

From: [USC ECG Learning Center](#)

Features of Normal ECGs

P wave

- Duration: 80-110ms
- Morphology: Upright in I, II; upright or inverted in aVF; inverted or biphasic in III, aVL, V1, V2.
- Amplitude: <2.5mm

- In lead V1, positive deflection <1.5mm and negative deflection <1mm

PR interval

- Duration 120-200ms

QRS complex

- Duration 60-100ms
- Axis: -30° to +90°
- Normal Q waves: small (<40ms in duration and <2mm in height, in most leads)

ST segment

- Usually isoelectric (flat) but may vary by approximately 1mm above or below.

T wave

- Morphology: Upright in I, II, V3-V6. Inverted in aVR and V1. Maybe be upright, flat, or biphasic in other leads.
- Amplitude: Usually <6mm (limb leads) or <10mm (precordial leads)

QT interval

- Corrected QT interval (QTc) duration: 300-460ms
- To calculate QTc: $QTc = QT/\sqrt{RR \text{ interval}}$

Sinus rhythm

- Normal P wave morphology and axis
- Every P wave is followed by a QRS complex, and vice-versa
- Atrial rate is 60-100 bpm and regular

Just a few of many irregularities in ECGs:

Sinus arrhythmia

- Normal P wave morphology and axis
- Gradual change in PP interval
- Longest and shortest PP intervals vary by >160ms or 10%

Sinus bradycardia

- Normal P wave
- Rate <60 bpm

Sinus tachycardia

- Normal P wave
- Rate >100 bpm