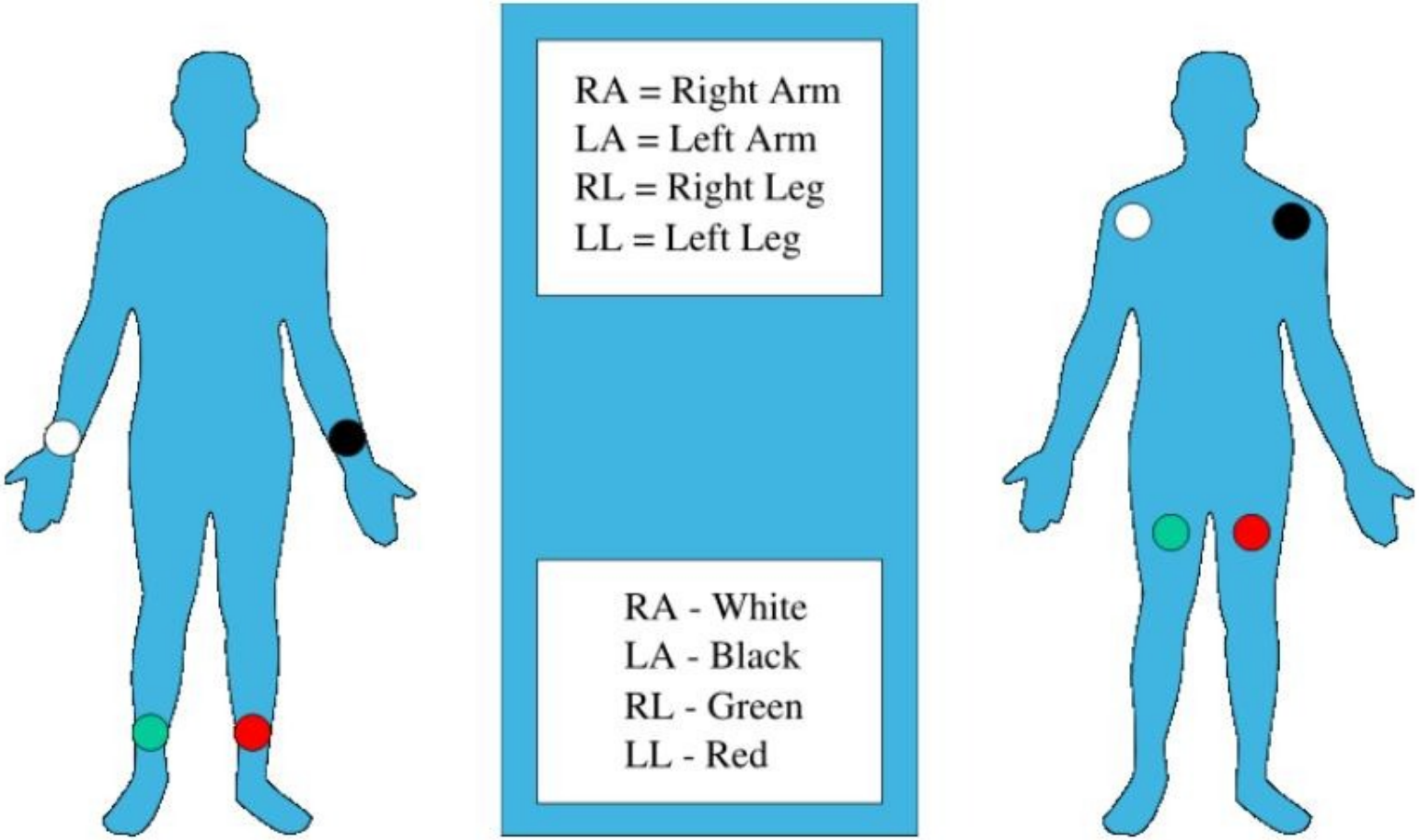
Biosignals and Systems

Lecture 4

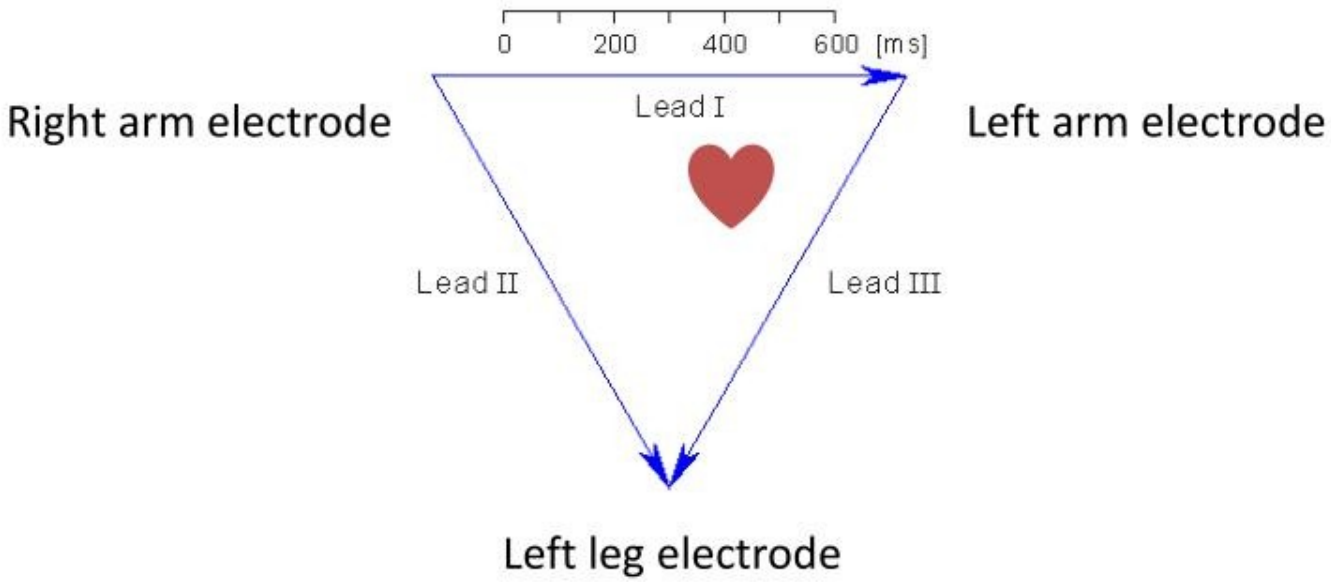
ECG

Standard external ECG starts with three electrodes and four wires.

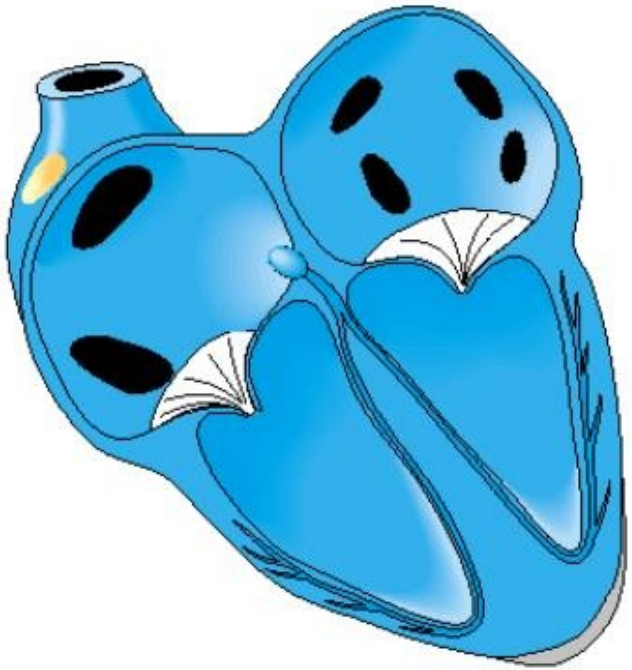


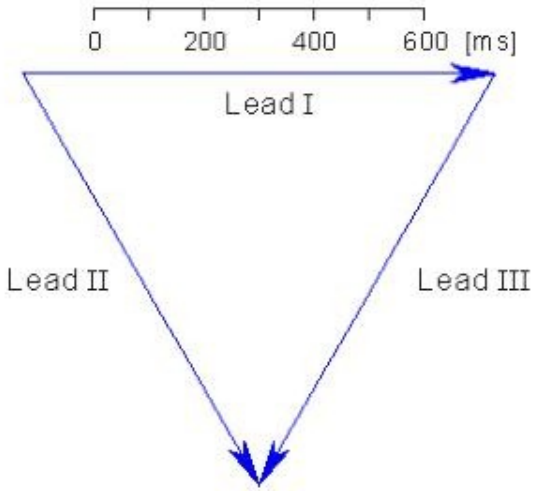
Right leg is typically connected to ground or a driven-right-leg circuit.
Voltages from the other three electrodes are combined to create 6 leads.

Standard ECG electrodes/leads



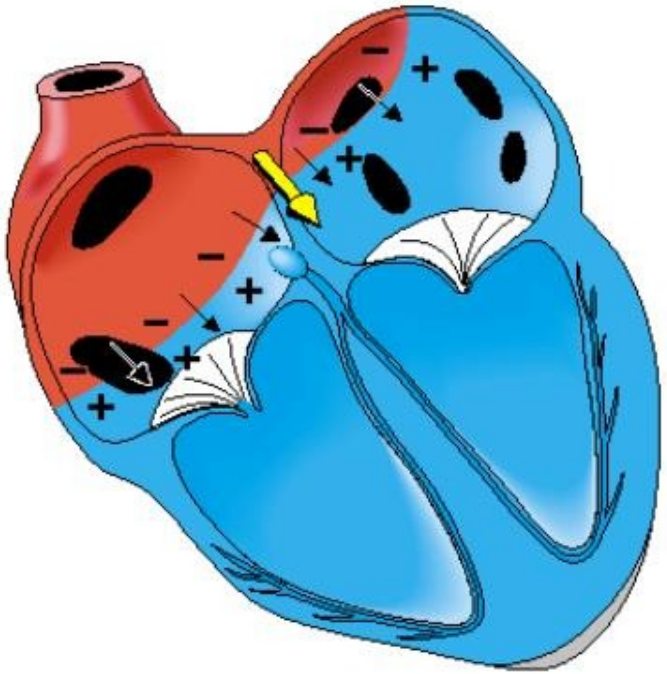
Heart at equilibrium polarization
No cardiac vector

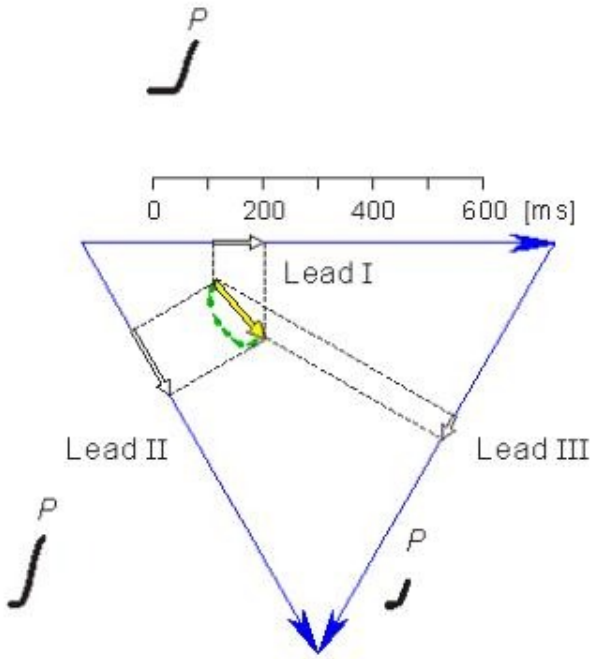




From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

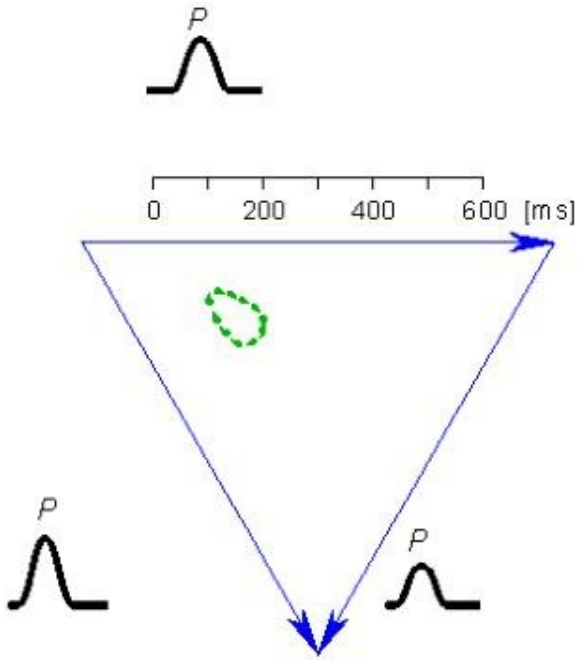
Atria depolarize
Cell exteriors become more negative as Na+ enters the cell





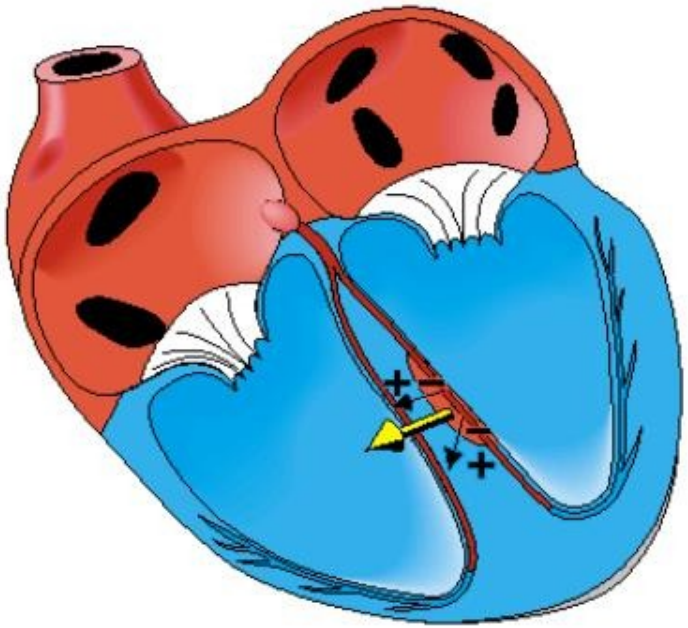
From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

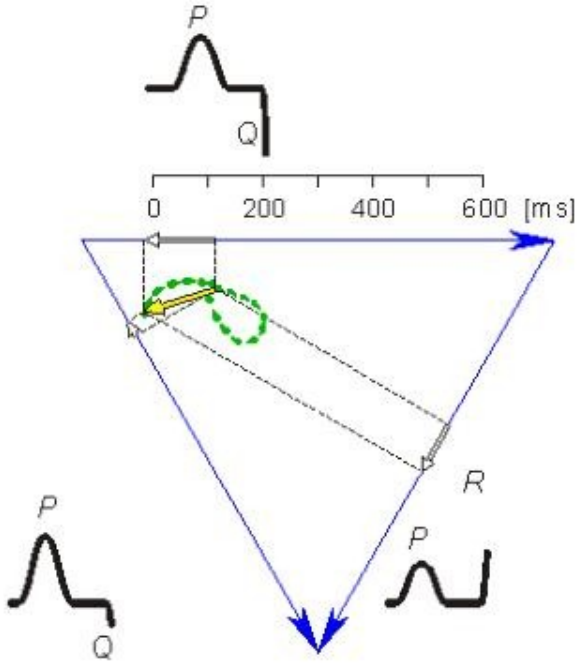
Pause at the AV node



From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

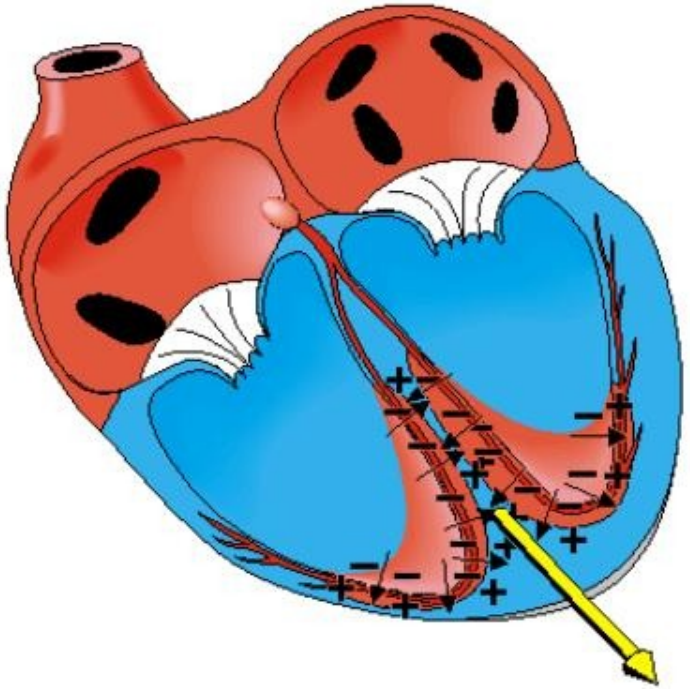
Septal depolarization begins

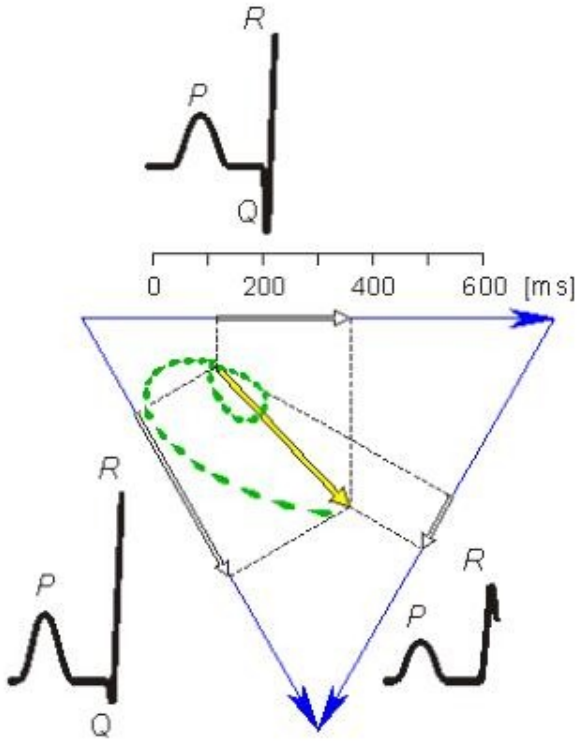




From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

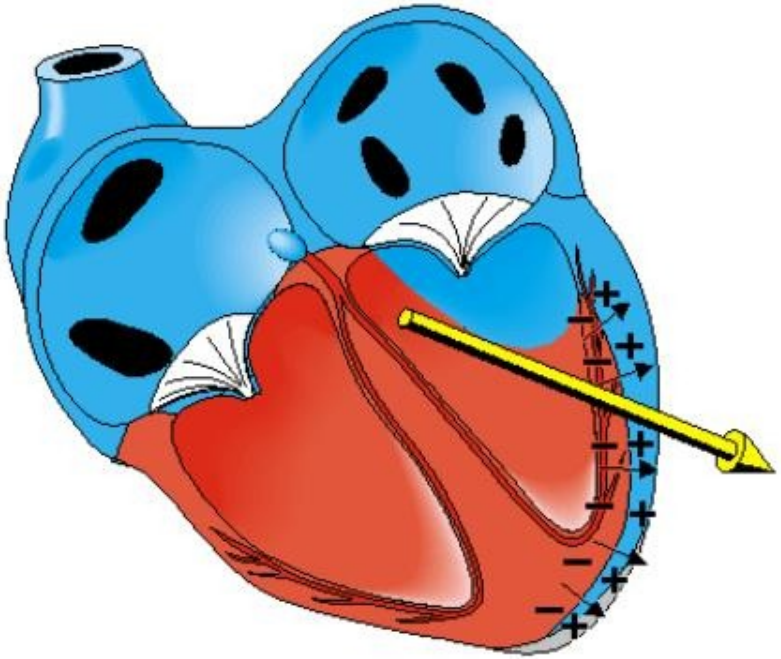
Ventricular depolarization continues

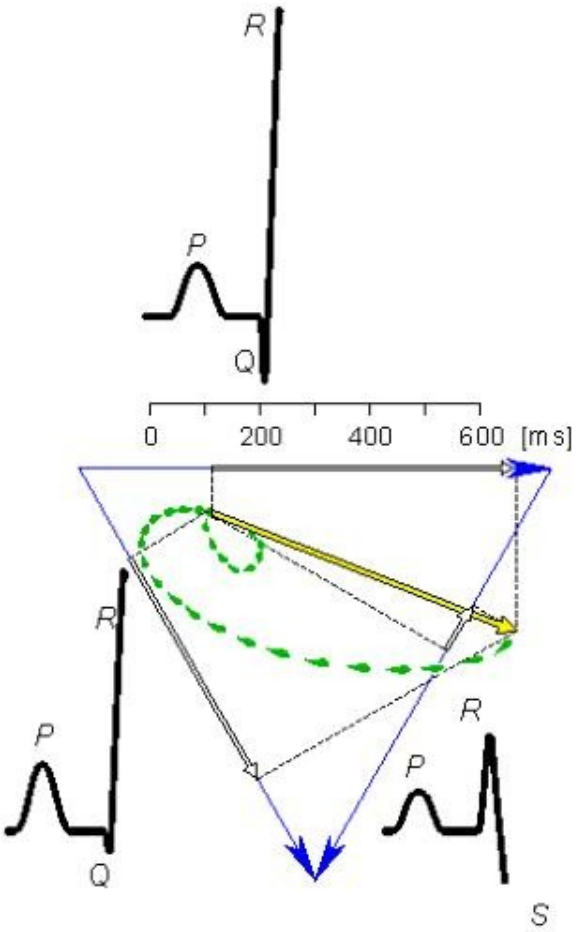




From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

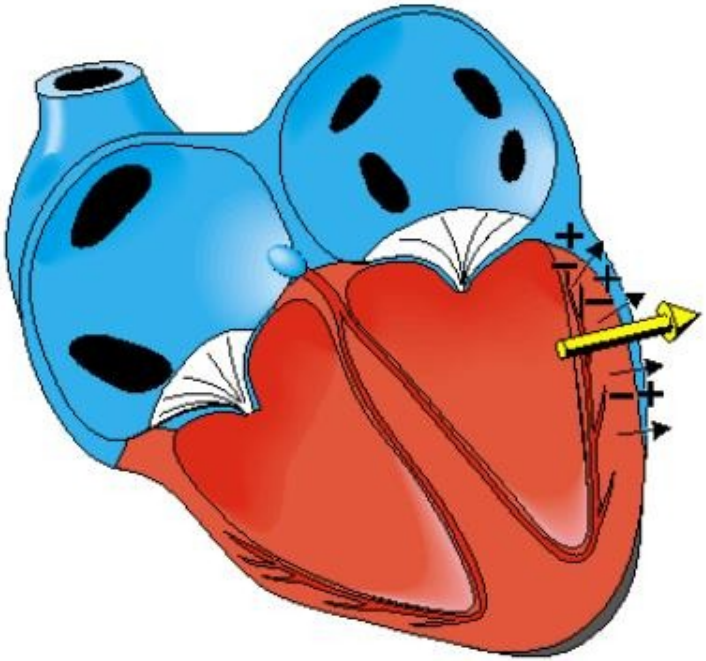
Ventricular depolarization continues on left side (more muscle, must pump to entire body)

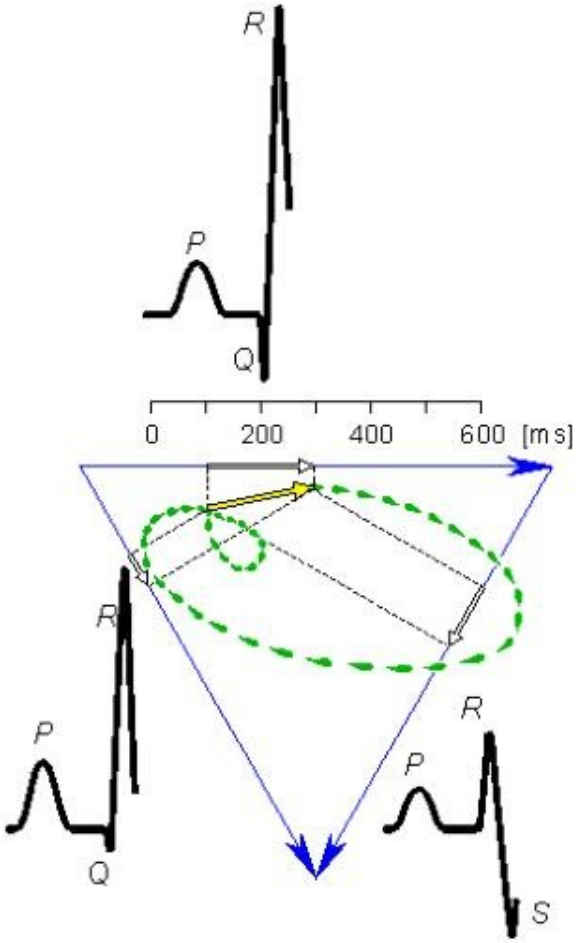




Note that atria repolarized, but we didn't even notice because ventricles are so much bigger and create a much bigger voltage.

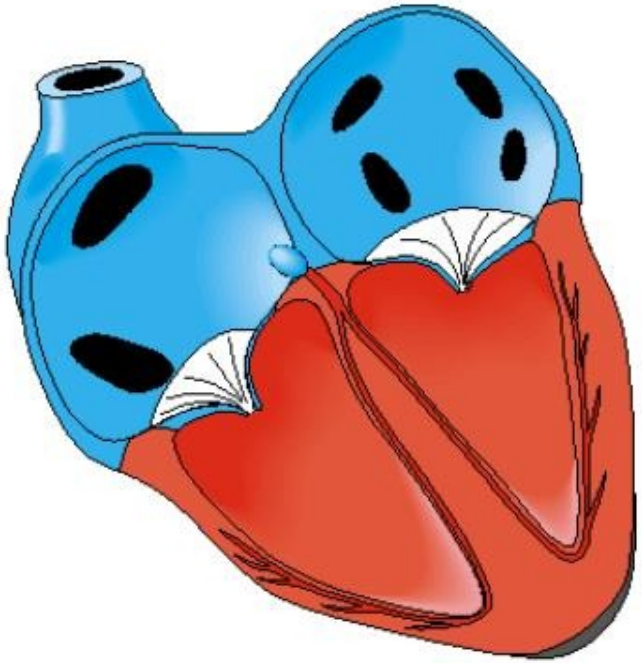
From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

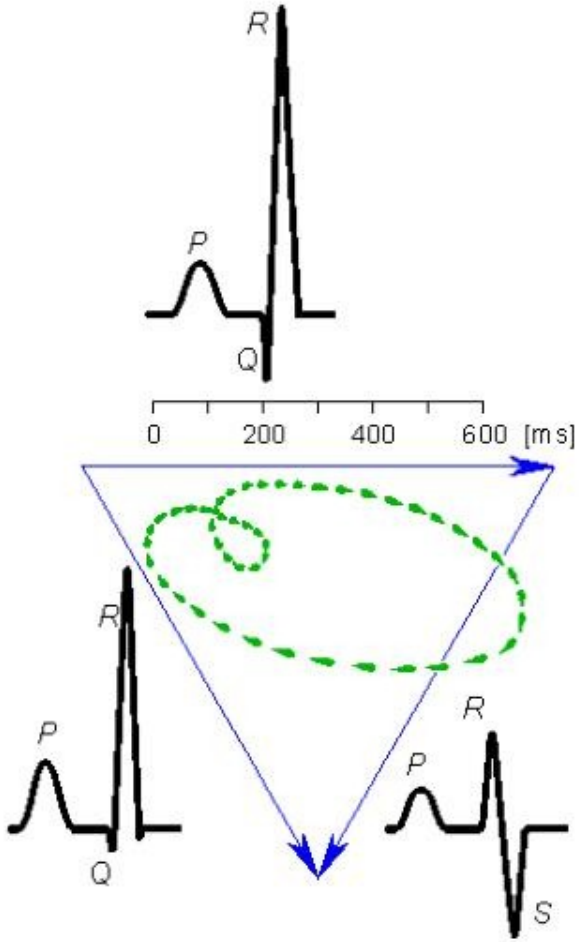




From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

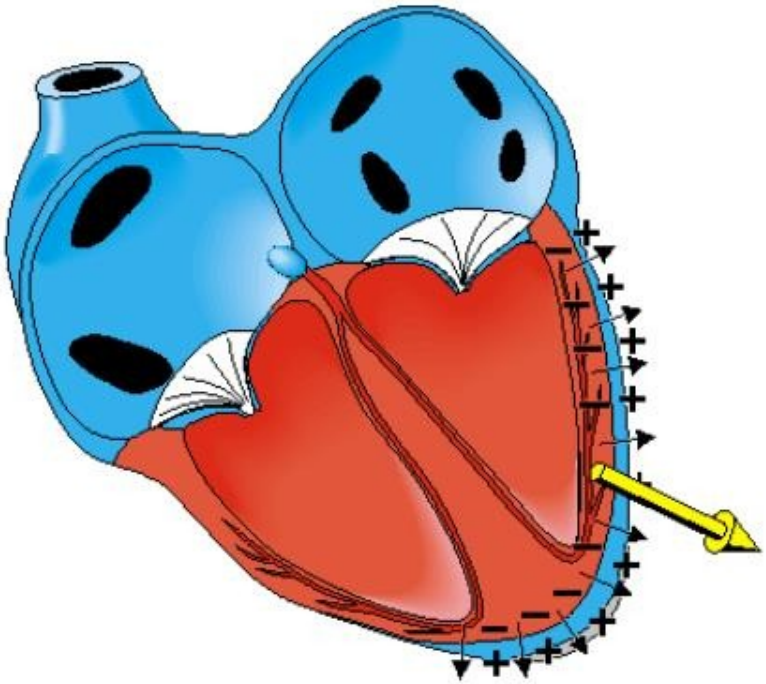
Complete ventricular depolarization

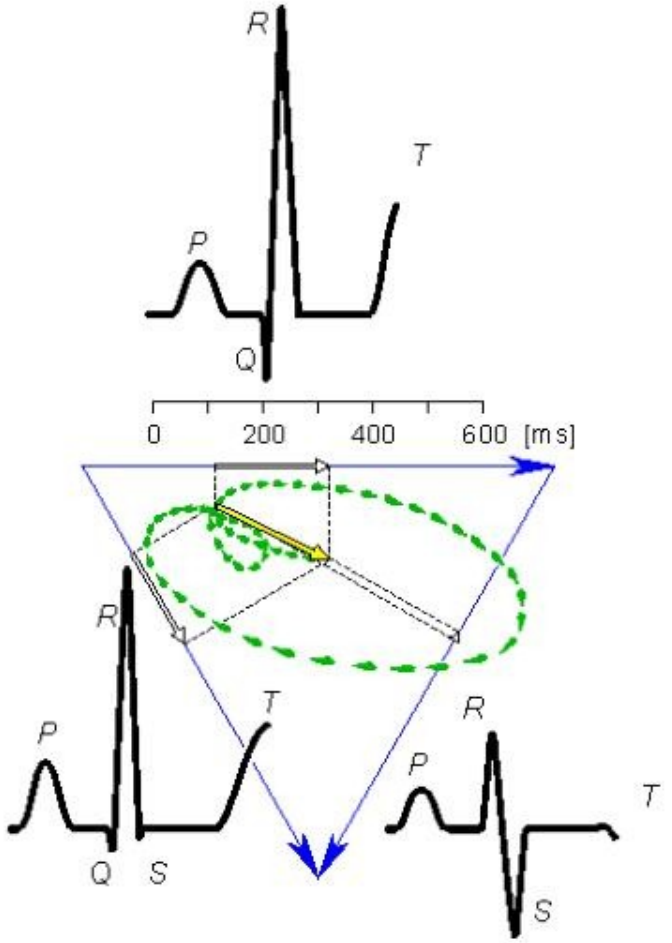




From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

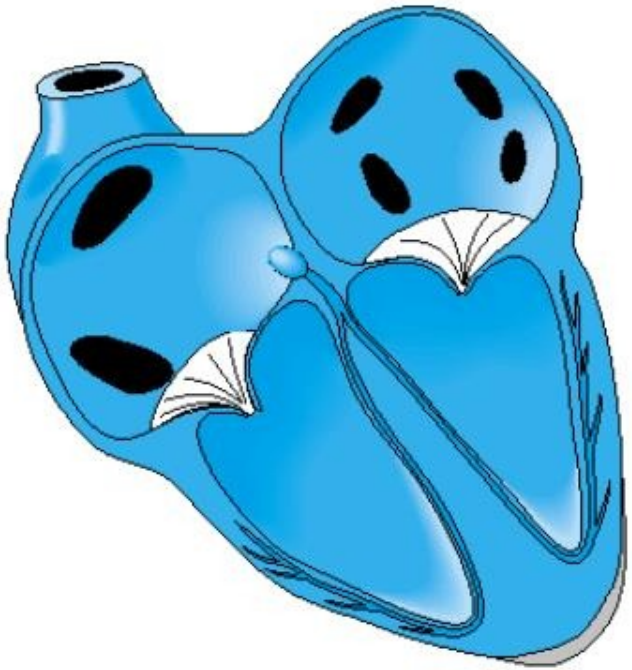
Ventricular repolarization begins

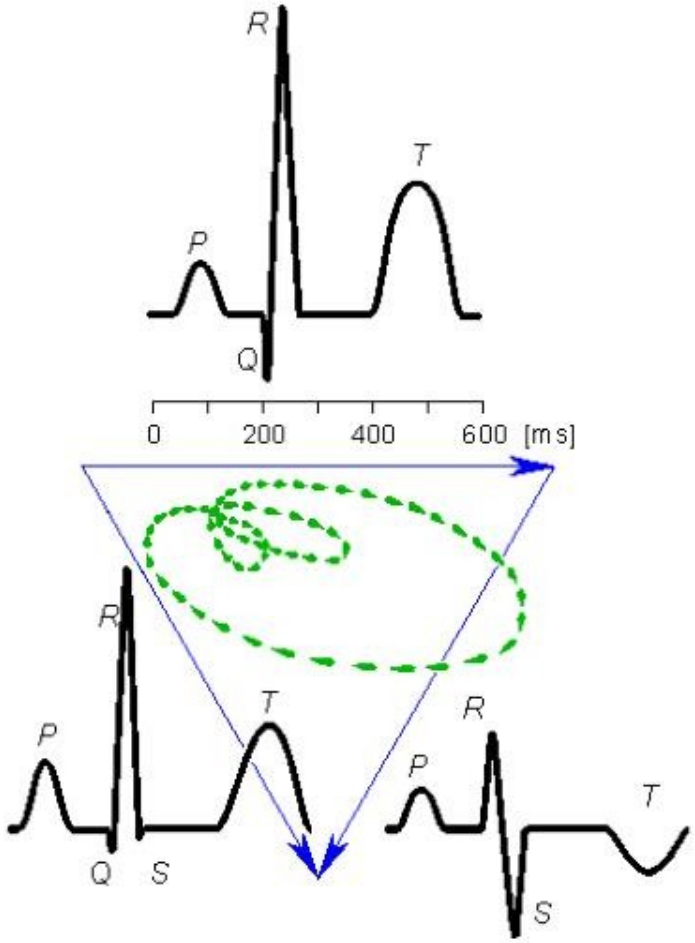




From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

Heart is polarized, ready to beat again





From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

Standard Lead II ECG with standard scaling

P wave – atrial depolarization

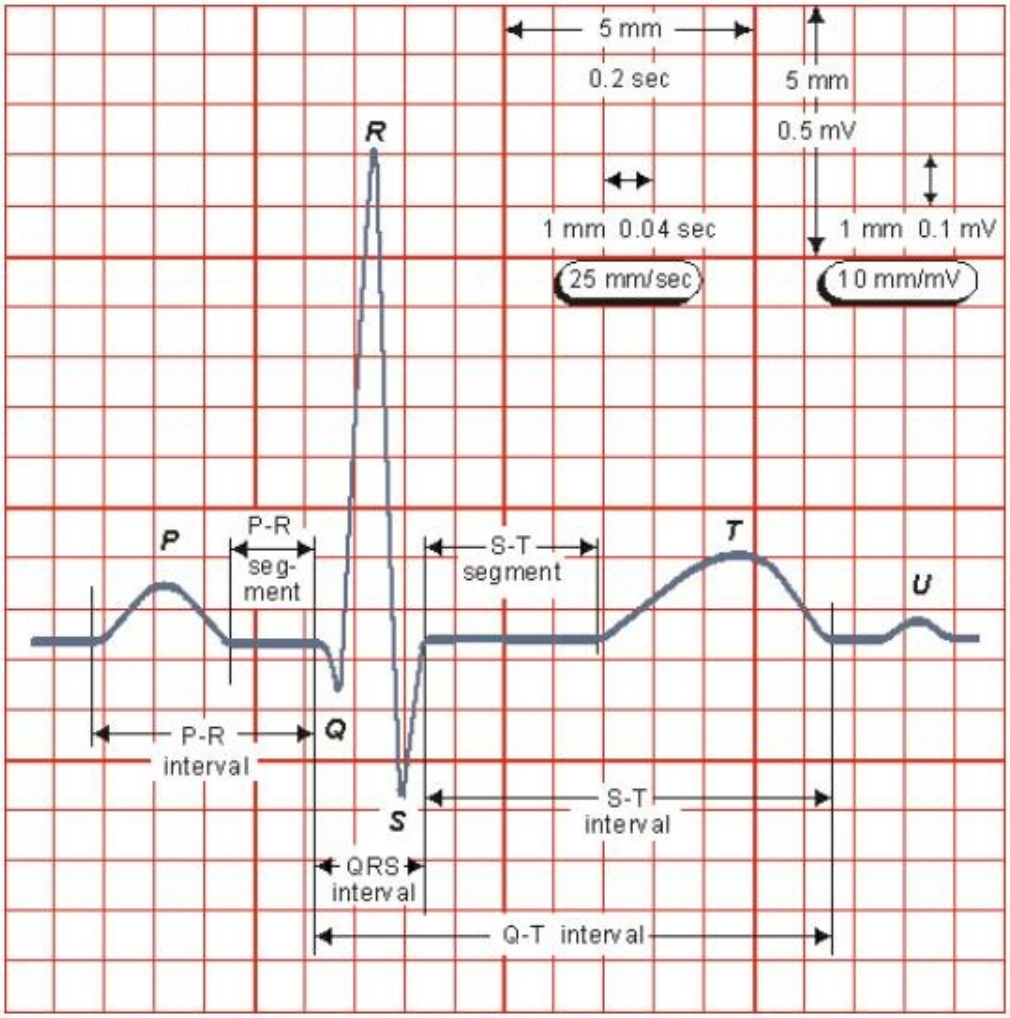
PR interval – pause at AV node

QRS complex – ventricular depolarization (hiding atrial repolarization)

ST interval – plateau in action potential of ventricular cells

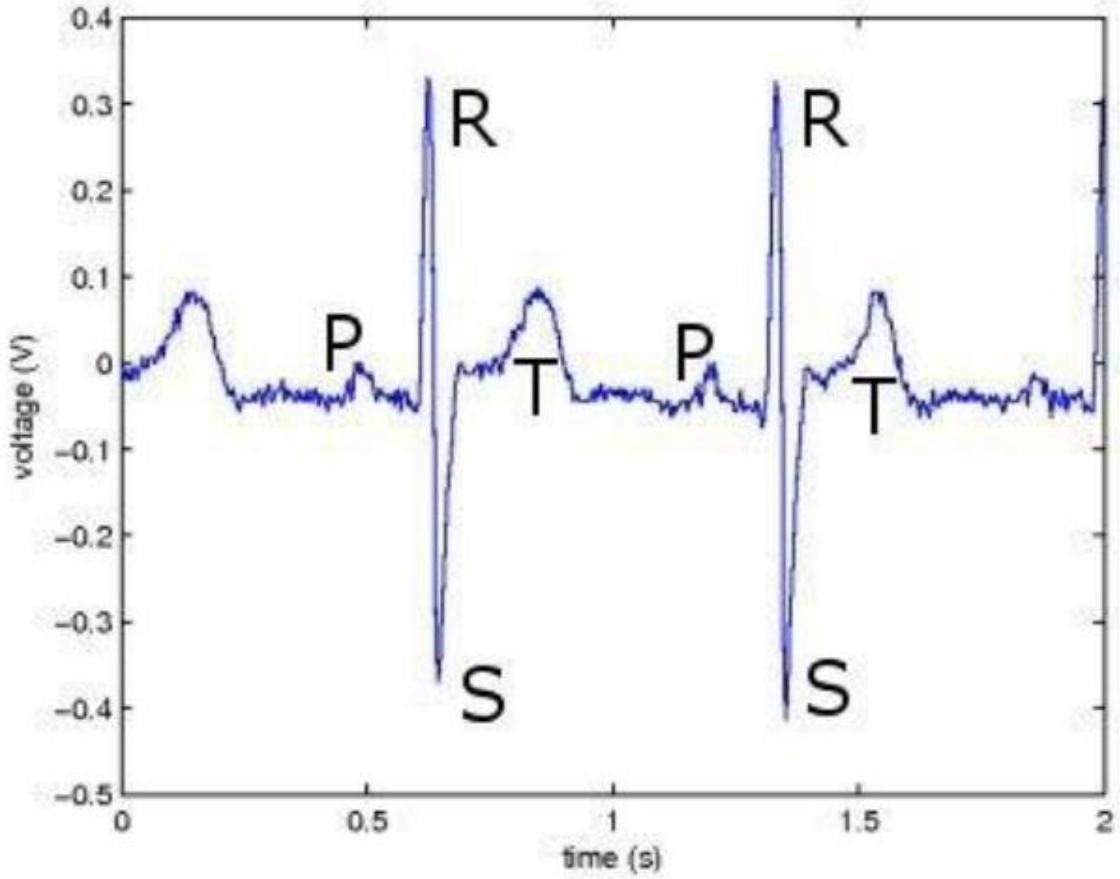
T wave – ventricular repolarization

U wave – often not seen; repolarization of muscles that aid in opening mitral and aortic valves?



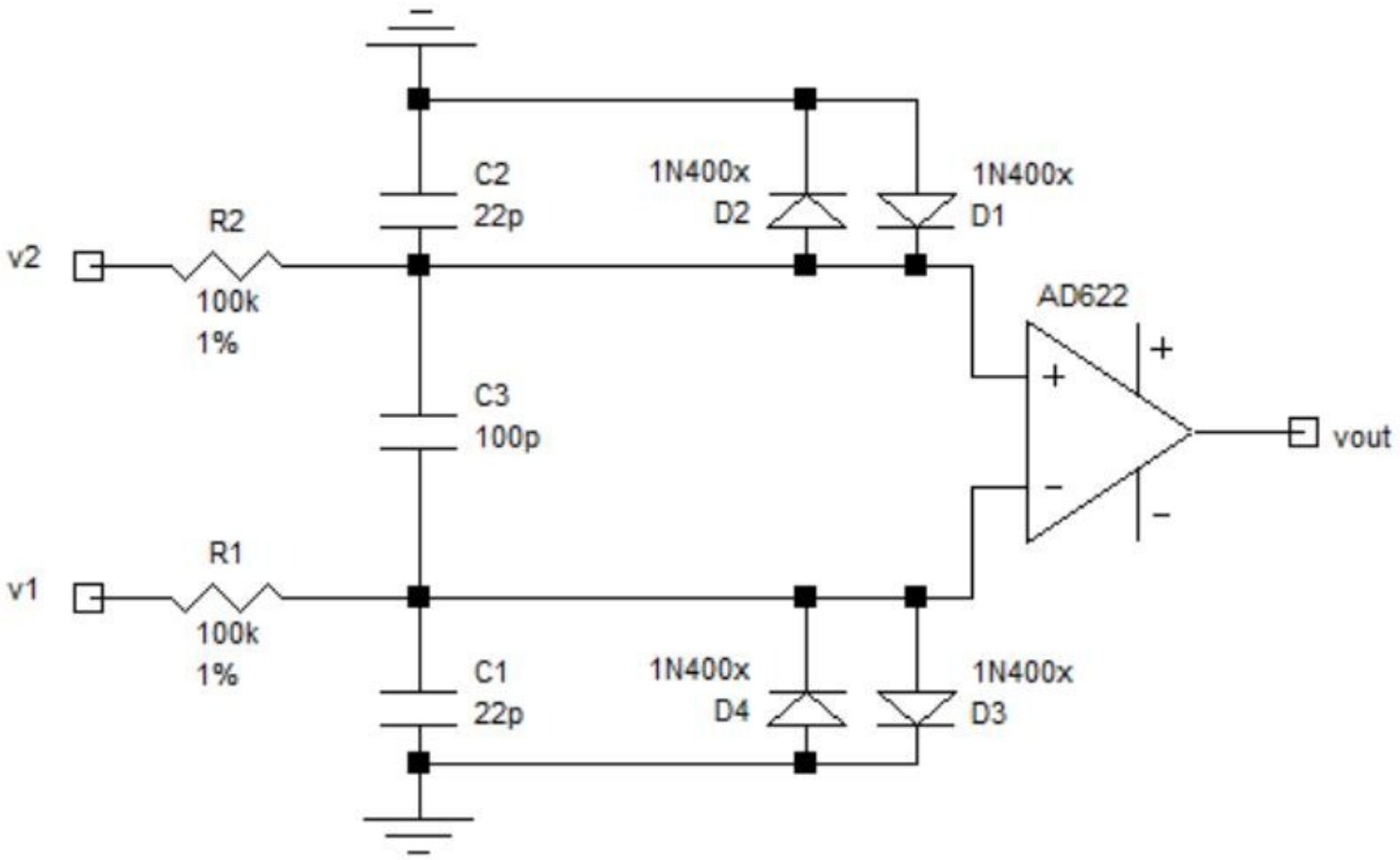
From *Bioelectromagnetism*, http://www.bem.fi/book/index.htm

Lead II showing characteristic features

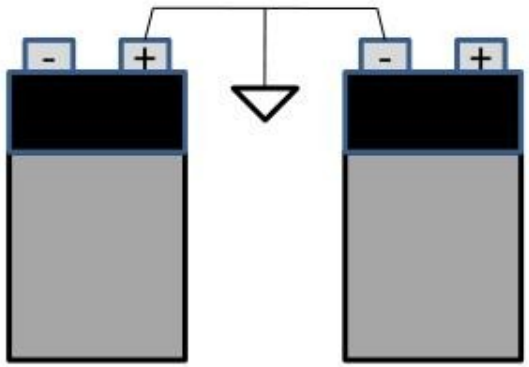


This chart does not show a strong Q (downward deflection just prior to R wave).

Biopotential amplifier (saved from this week, but retest next)

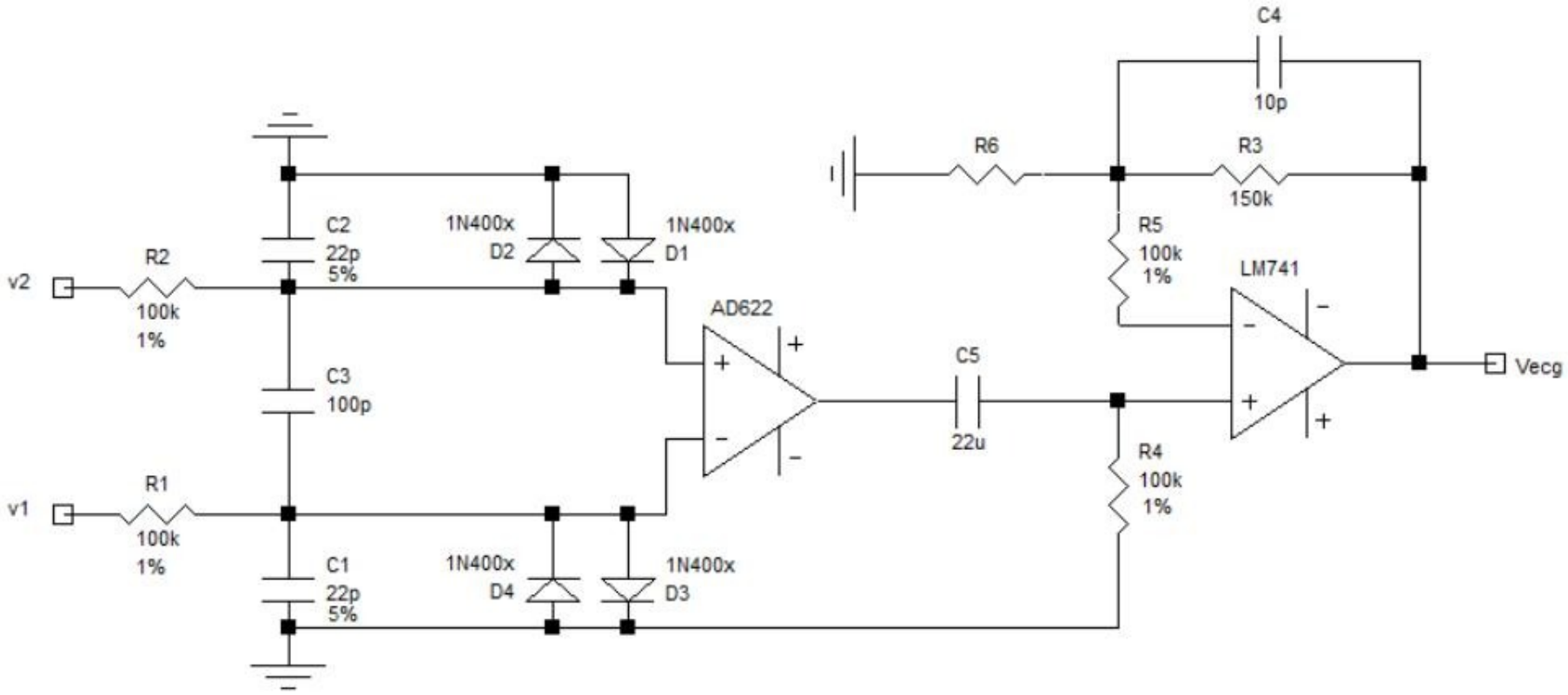


Next week we will be powering it with 9V batteries

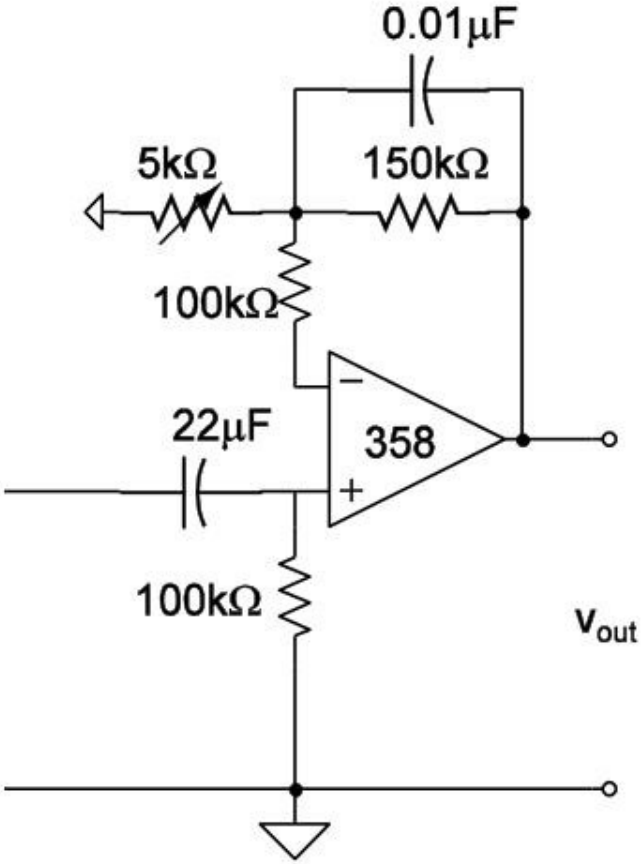


- Connected to circuit ground or reference, not earth ground
- Test batteries for freshness

ECG has additional filtering and gain



What does this circuit do?



- Analyze it in the frequency domain (i.e., with phasors)

```
c = 22e-6;
r = 100e3;
rf = 150e3;
cf = 0.01e-6;
ri = 5e3;
```

- Define component values

```
jw = tf('s');
```

- Define Fourier or phasor variable (really LaPlace variable, but we just care about jw)

```
Ghp = jw*r*c/(1 + jw*r*c);
```

- Define transfer function of high pass filter

```
zcf = 1/(jw*cf);
zf = rf*zcf/(rf + zcf);
zi = ri;
```

- Find impedances for op amp gain

```
Goa = (1 + zf/zi);
```

- Define transfer function of op amp circuit

```
G = Ghp*Goa;
```

- Find overall gain

```
[mag, phase, w] = bode(G);
```

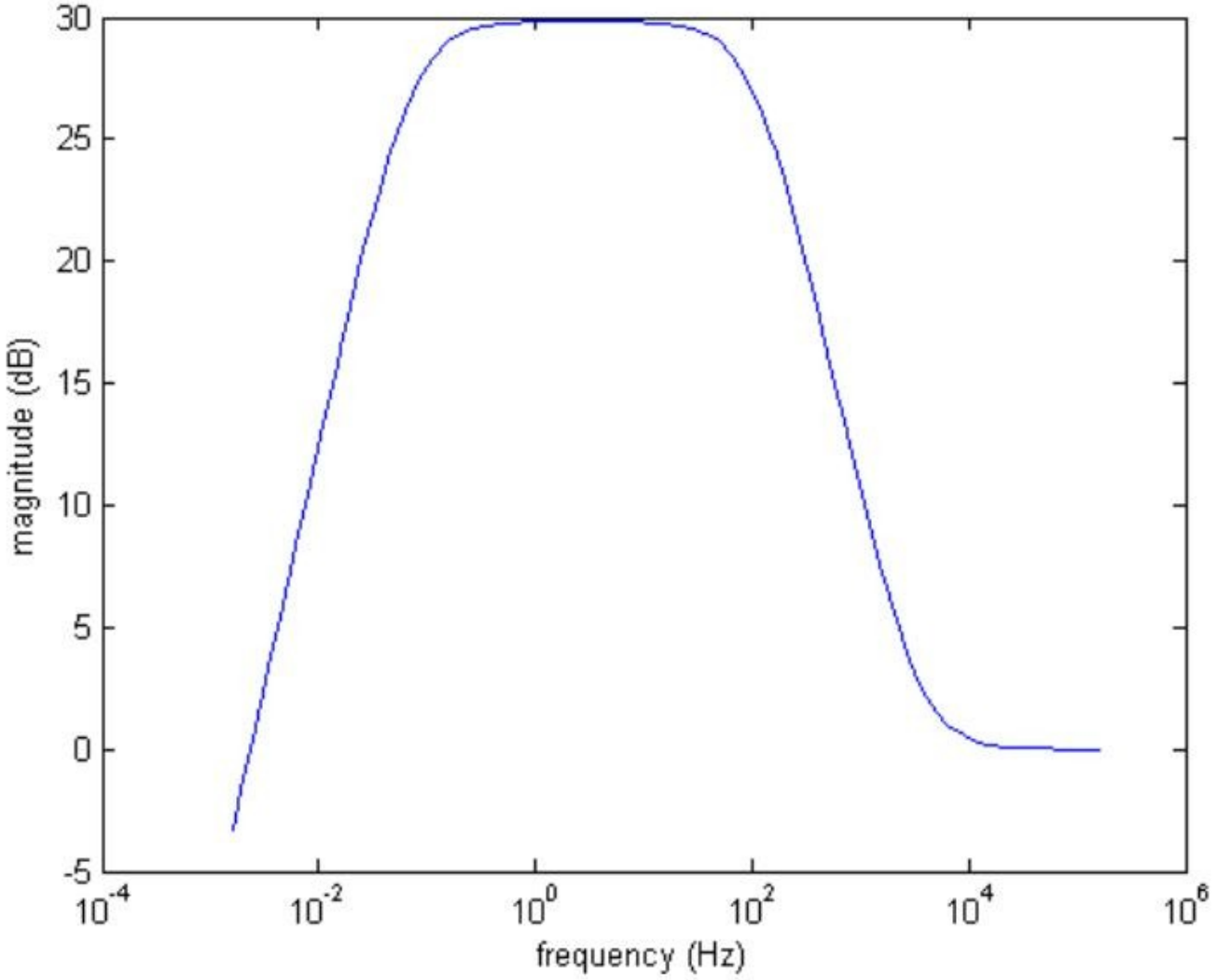
- Calculate Bode plot data

```
magdb = 20*log10(squeeze(mag));
f = w'/2/pi;
```

- Find magnitude in dB
- Calculate frequency in Hz

```
semilogx(f, magdb);
xlabel('frequency (Hz)');ylabel('magnitude (dB)');
```

- Plot on log axis
- Label axes


30
25
20
15
10
5
0
-5
magnitude (dB)
10^{-4}
10^{-2}
10^{0}
10^{2}
10^{4}
10^{6}
frequency (Hz)

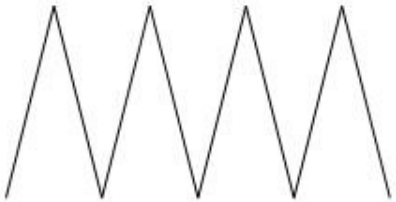
Add software filtering

- Line noise
- Additional high- and low-pass

- Show both filtered and unfiltered for comparison

Testing your ECG circuit

1. Test with a sawtooth waveform at 1-2 Hz, first with DC power supply, then with batteries.



2. Then test with the ECG simulator and batteries.

We only have one so share!

You can also test with the PC

- Course website contains directions for downloading ECG data in an audio file (.wav)
- Play the file with Windows Media Player
  - Volume controls amplitude (turn volume down)
  - Set to repeat
- Cables with a headphone plug on one end and breadboard wires on the other will be provided

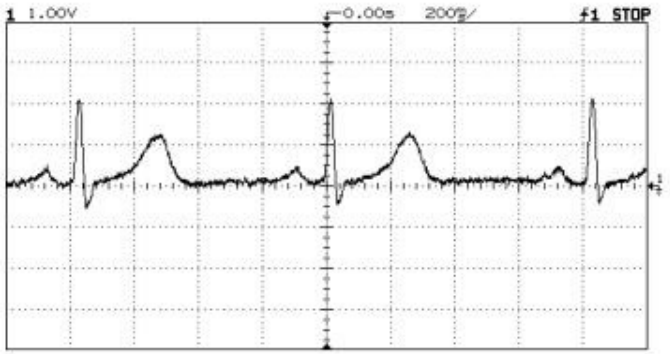


Table 6.1 Summary of Performance Requirements for Electrocardiographs (Anonymous, 1991)

Section	Requirement Description	Min/max	Units	Min/Max Value
3.2.1	Operating conditions:			
	Line voltage	Range	V rms	104 to 1127
	Frequency	Range	Hz	60 ± 1
	Temperature	Range	°C	25 ± 10
	Relative humidity	Range	%	50 ± 20
	Atmospheric pressure	Range	Pa	7×10^4 to 10.6×10^4
3.2.2	Lead definition (number of leads):	NA	NA	Table 3
	Single-channel	Min	NA	7
	Three-channel	Min	NA	12
3.2.3	Input Dynamic Range:			
	Range of linear operations of input signal	Min	mV	±5
	Slew rate change	Max	mV/s	320
	DC offset voltage range	Min	mV	±300
	Allowed variation of amplitude with dc offset	Max	%	±5

Three electrodes per team

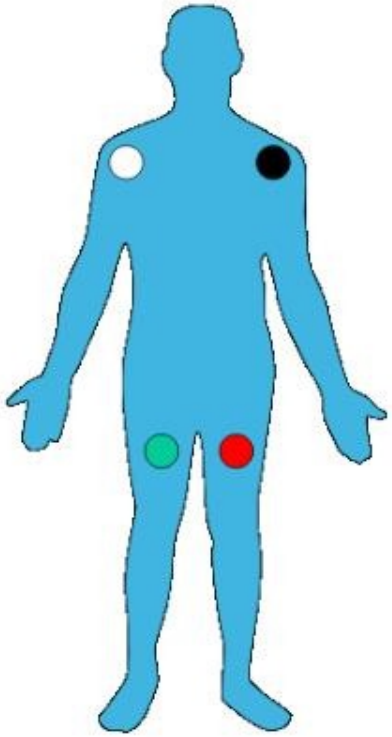
- Apply to upper arms and lower thigh
  - Wear shorts if possible
- Use short black, green, and white wires with alligator clips to attach electrodes to circuit
- Use alcohol to remove

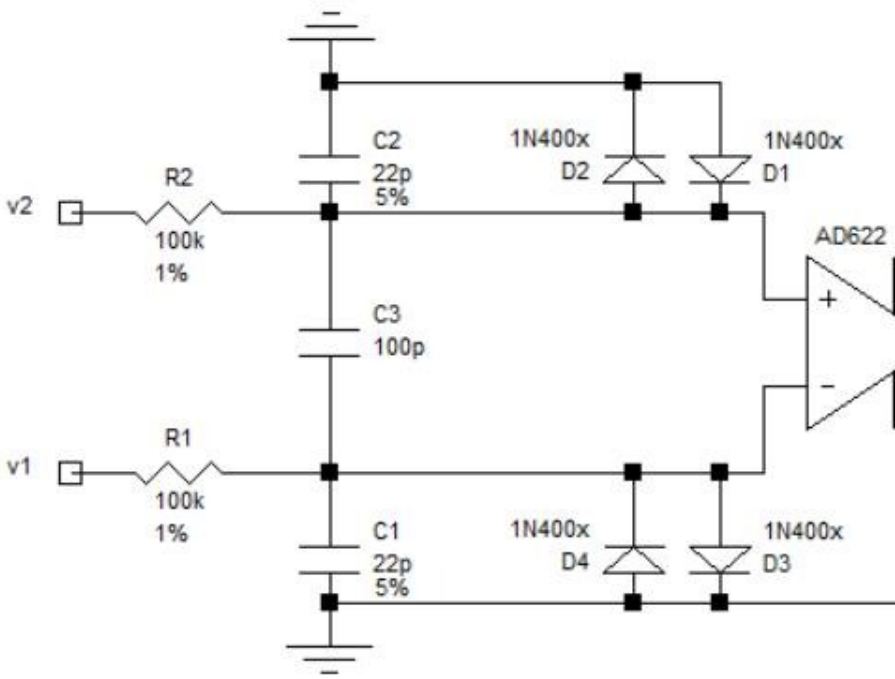
Floating disc Ag/AgCl electrodes
Designed for short-term monitoring

What should be attached to the three circuit inputs to measure Lead I?

RA = Right Arm
LA = Left Arm
RL = Right Leg
LL = Left Leg

RA - White
LA - Black
RL - Green
LL - Red





What should be attached to the three circuit inputs to measure Lead II?

RA = Right Arm
LA = Left Arm
RL = Right Leg
LL = Left Leg

RA - White
LA - Black
RL - Green
LL - Red