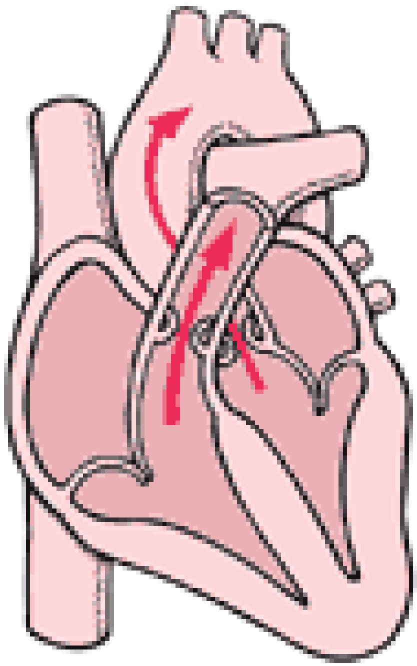
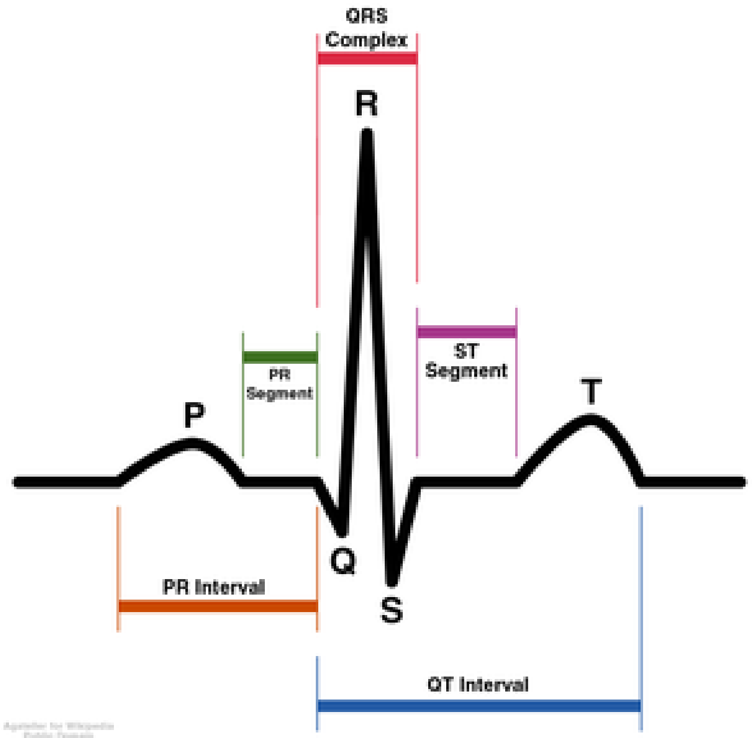
EGR111
Arrhythmia Project





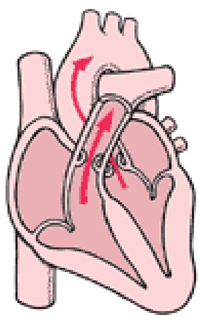
- This project is based on “**Arrhythmia Detection Algorithms for Implantable Cardioverter Defibrillators” by Dr. Amy Bell**

- **http://www.realworldengineering.org/index.php?page=project&project=233**

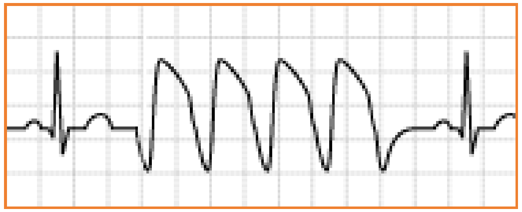
Outline

This presentation will cover a brief description of the heart and arrhythmias, a history of solutions, the technical challenges of the solutions, and our project.

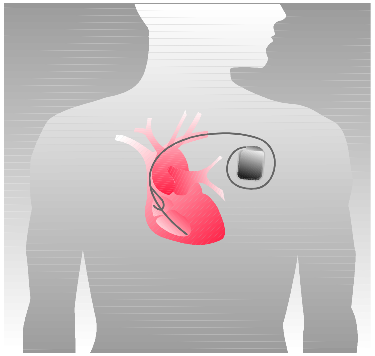
1. The heart



2. Heart Problems

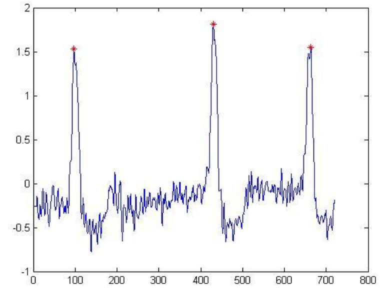


3. Solutions



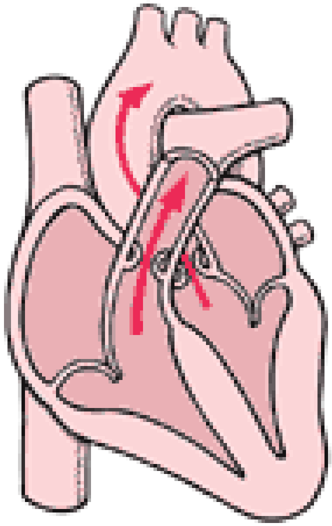
4. Technical challenges

5. Our Project

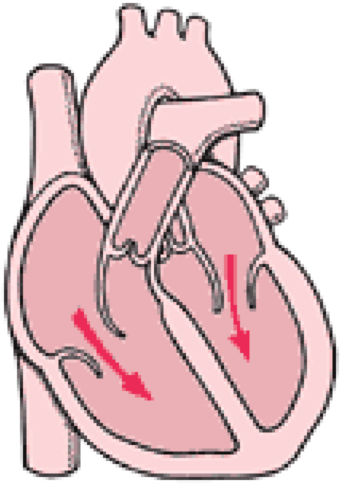


An average heart beats 100,000 times a day, pumping 2,000 gallons of blood through its chambers to the body and back to the heart.

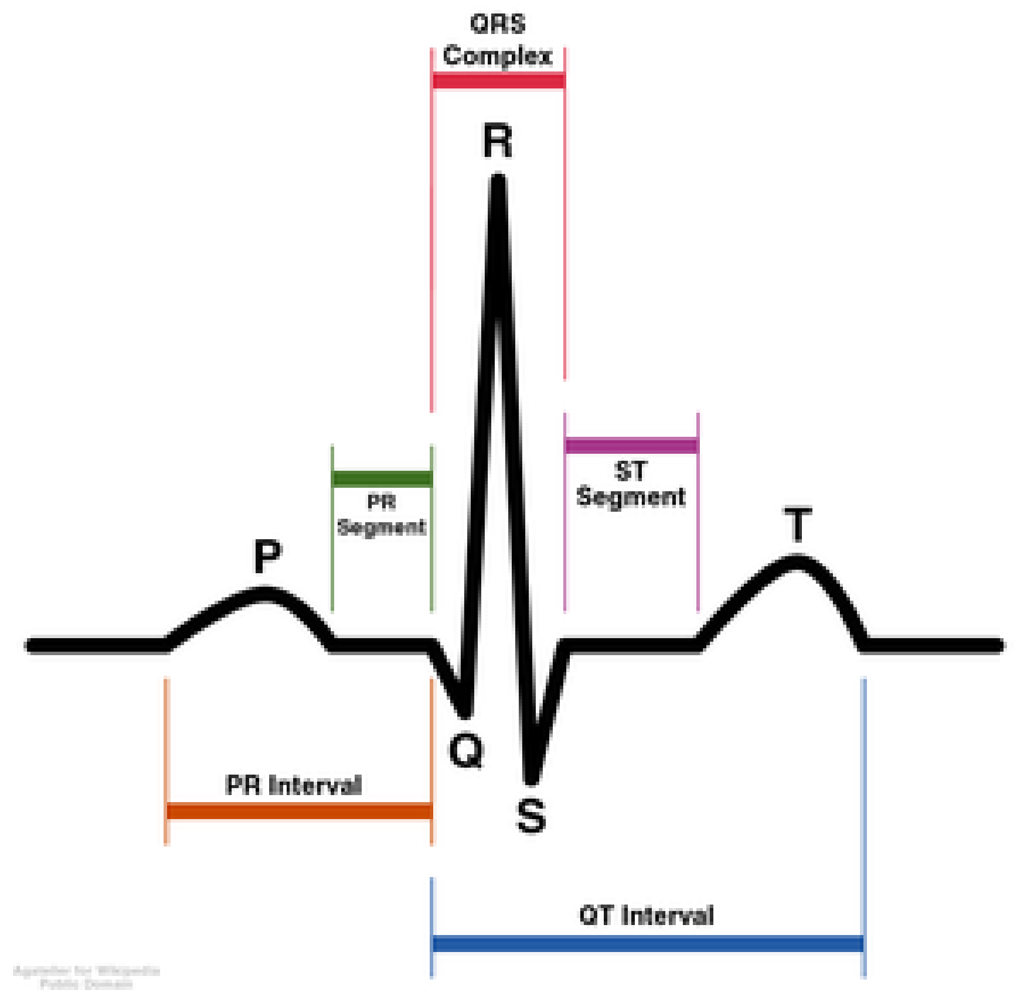
- An electrical impulse signals the heart's four chambers to contract, pushing blood out through the body.



- Then the heart relaxes.

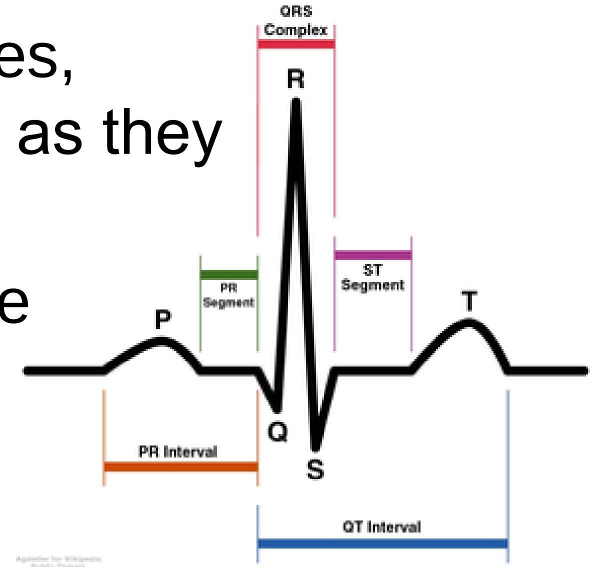


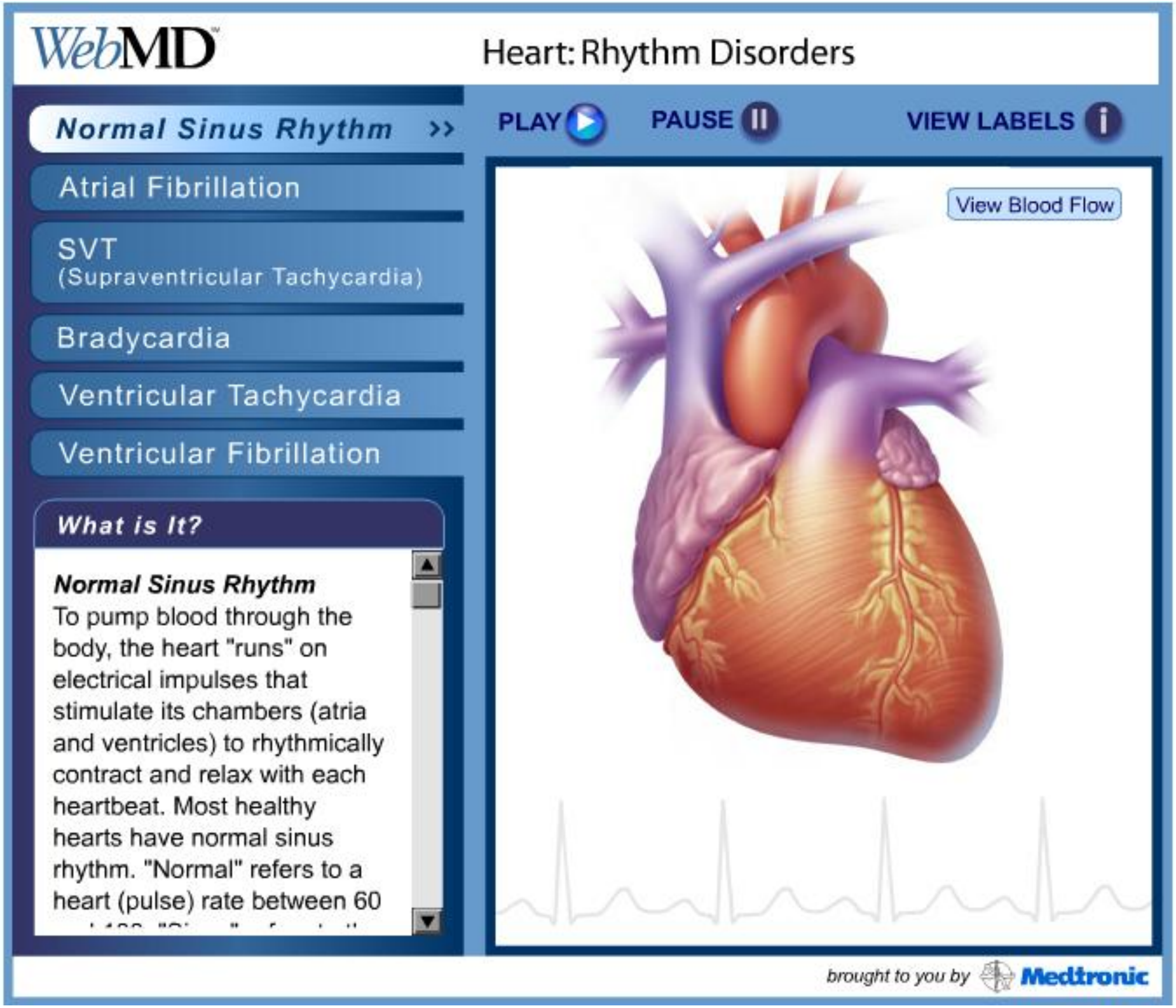
- The normal contract-relax cycle is called a Sinus Rhythm (SR)
- This cycle follows a regular PQRST pattern.



Electrical signals follow a defined path through the heart during normal sinus rhythm.

- The electrical impulse that starts each beat originates in the sinoatrial (SA) node. The electricity then flows through the atria, upper chambers, of the heart. This is represented in an ECG by the “P-wave”.
- Electricity next flows through the ventricles, bottom chambers, in the “QRS-complex” as they contract and push blood out to the body.
- Finally, the heart resets electrically on the “T-wave” and is ready for the next beat.



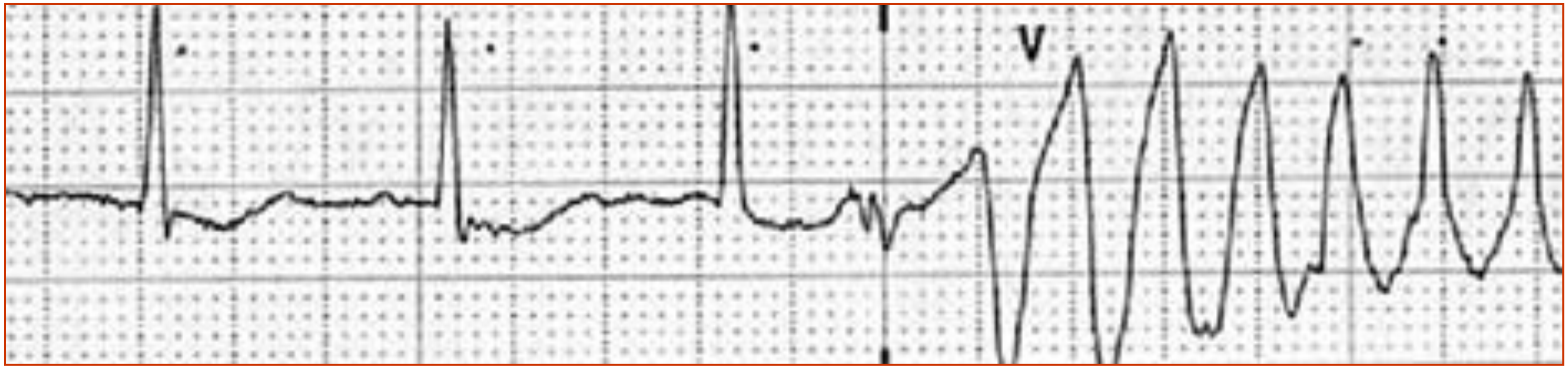


[See animation]

Many forms of heart disease can interrupt the normal contract-relax cycle and cause abnormally fast or slow heart rates.

- ***Cardiac Arrhythmia*: Irregularity of the heartbeat caused by damage to (or defect in) the heart tissue and its electrical system.**

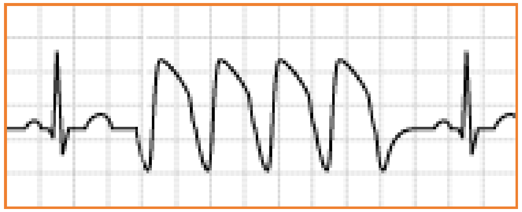
Sinus Rhythm Cardiac Arrhythmia



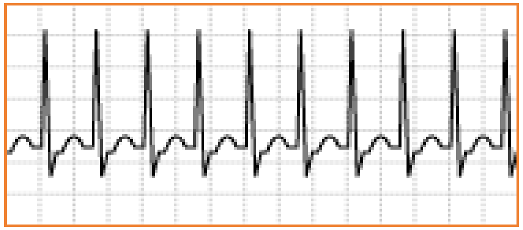
There are several different types of Cardiac Arrhythmias, some are not as severe, while others are considered life threatening.

- **Sinus Rhythm (normal heartbeat)**

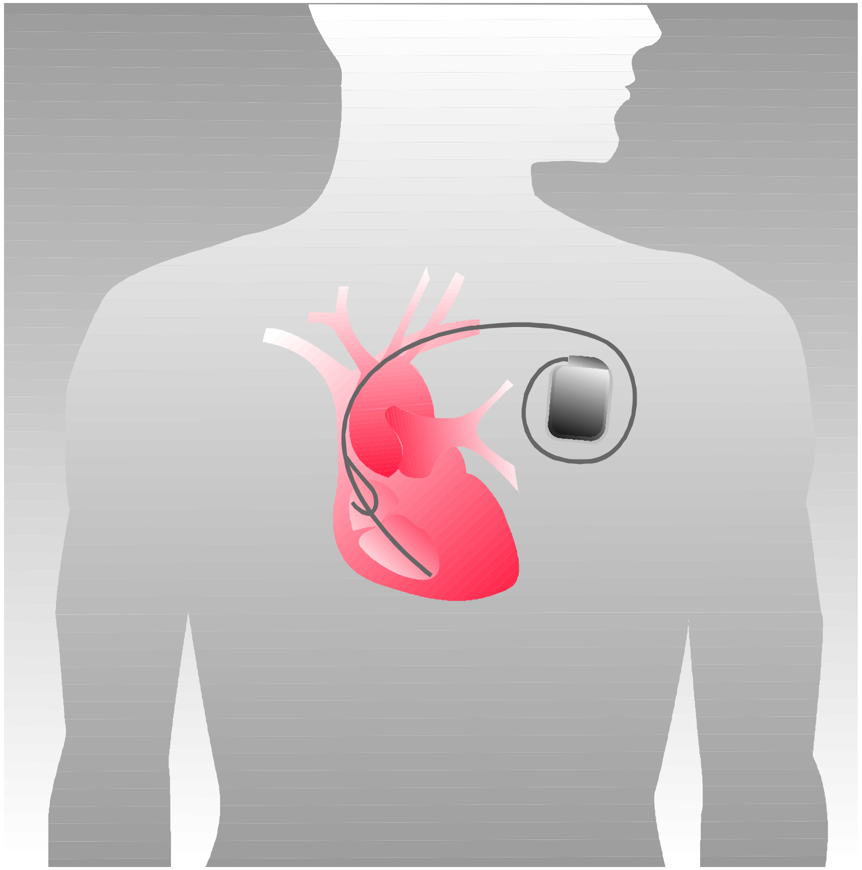
- **Ventricular tachycardia (VT)** – the heart beats too fast and may not pump enough blood. Very dangerous and requires immediate treatment.



- **Paroxysmal supraventricular tachycardia (SVT)** – The heart beats fast and may feel unpleasant. However, it is usually not life threatening and does not require treatment.



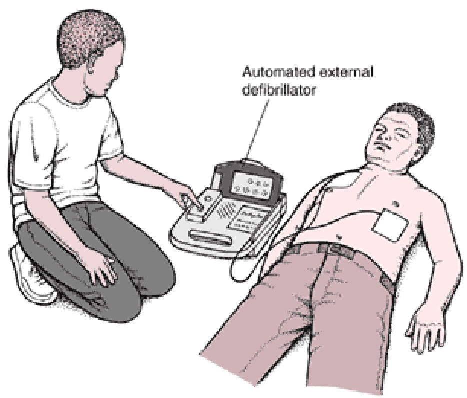
The Solutions



Before the 1960's no treatment existed for cardiac arrhythmia.

- The 1960's saw the introduction of **CPR**, cardiopulmonary resuscitation.

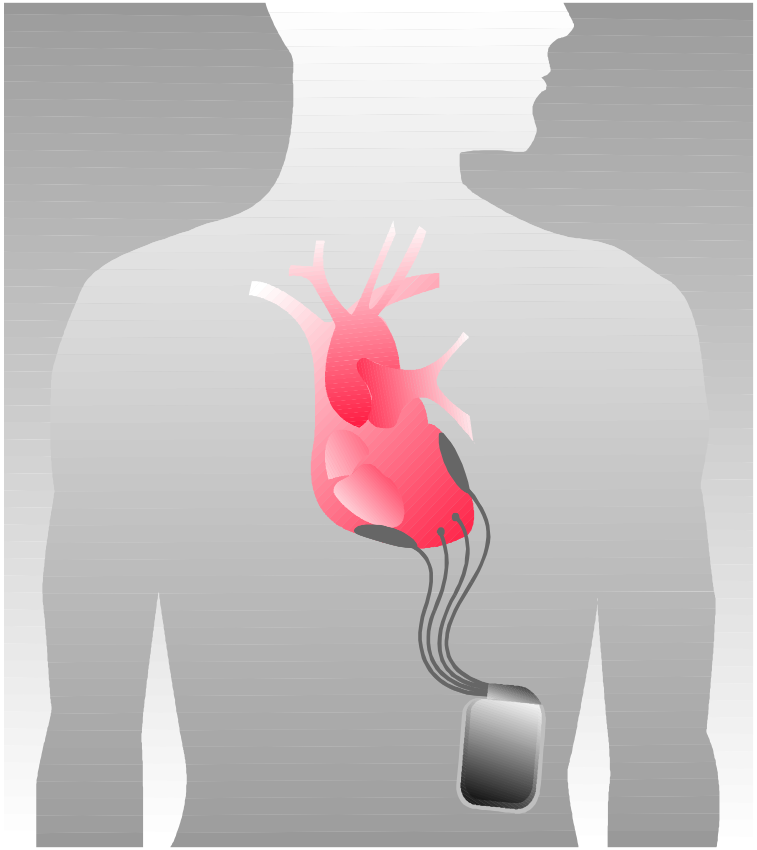
- **External defibrillation** also became a tool, using an electric shock to stop cardiac arrhythmia and restart the heart.



Implantable Cardioverter Defibrillators (ICD's) were first introduced in the 1980's.

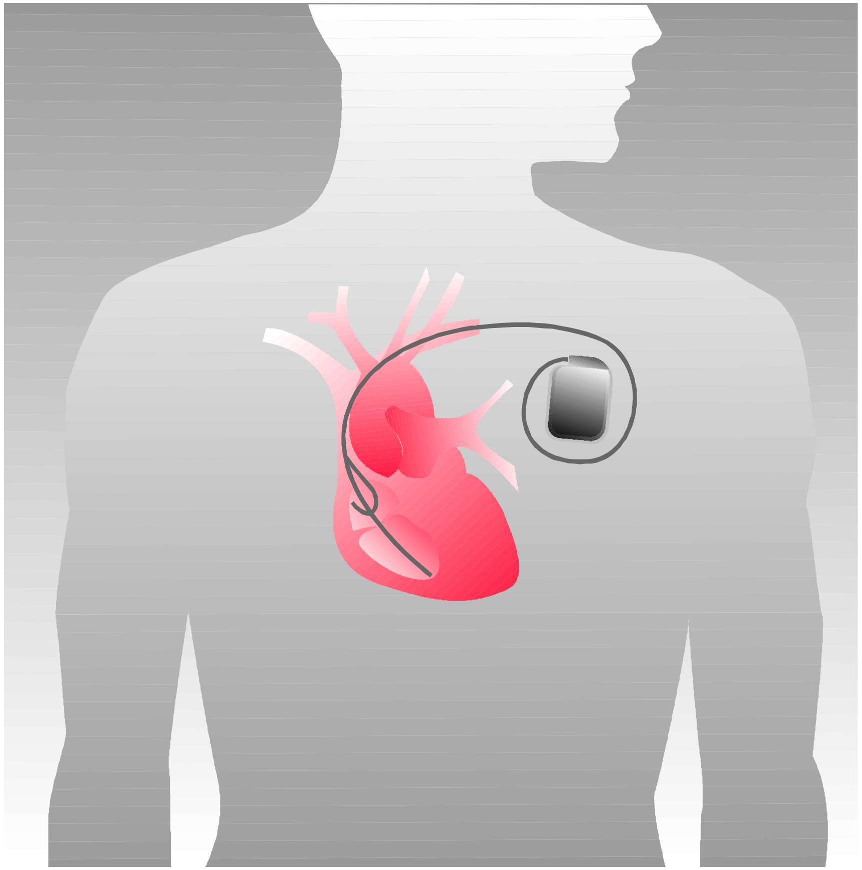
- These ICD's were large and required major surgery to be implanted in the patient's abdomen.

- These devices were reserved only for the highest risk patients and only lasted 18 months after being implanted.



Today's ICD devices are smaller and more effective than those used previously.

- Require only simple, local surgery to be implanted in the chest.
- Offer programmable therapy (varying degrees of electric shock): about 300 J in 4-12 msec
- Battery life of up to 9 years.



ICDs versus Pacemakers. What’s the difference?

- Pacemakers and ICDs are very similar, but they are not the same thing.

- Pacemakers send electrical shocks to the heart in order to speed up a heart that is beating too slowly. These shocks are small and cannot be felt.

- ICDs shock the heart in order to slow down and correct a heart beat that is too fast. These shocks are large and are described as ‘being hit in the chest’.

Today's ICD devices allow people who have heart problems to live relatively normal lives.

- Many people both young and old can develop heart problems as the result of disease, defects, or injury due to accidents.
- Without treatment patients may not be able to be physically active and healthy. With an ICD device many patients are able to live normally active lives.

- In 2002 alone there were about 100,000 ICDs implanted in patients.

Technical Challenges

There are several technical challenges to consider when designing an ICD.

- The ICD is constantly monitoring the heart rhythm and must be able to quickly and accurately detect abnormal rhythms.

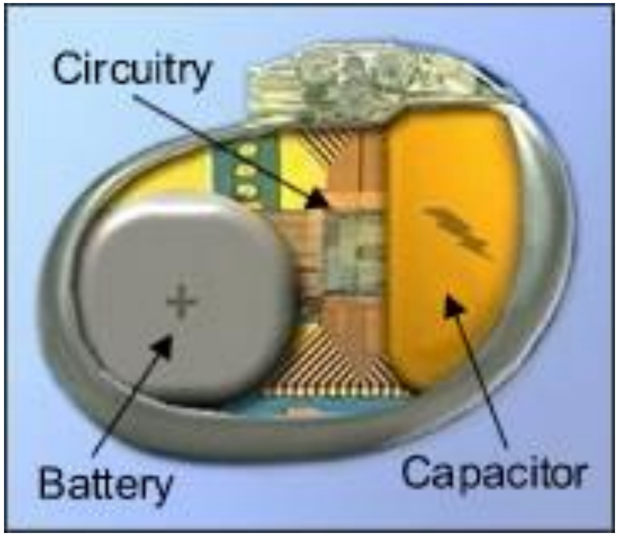
- **Speed** and **Accuracy** are the primary criteria for a good ICD ***detection algorithm***.

To be effective and practical an ICD must work continuously over a long period of time.

- A balance must be established between speed and accuracy while keeping battery life in mind.

- In general, faster algorithms are less accurate while slower algorithms are more accurate.

- These tradeoffs are constrained by possibility of death. An ICD cannot miss a VT but it also has to be fast enough to catch a VT in time.



An ICD that needs to be replaced every year is not very practical. Long battery life is essential to patients.

- The battery life of an ICD depends on the complexity of the detection algorithm.
  - The more complex the algorithm the more power and time needed to make a decision.

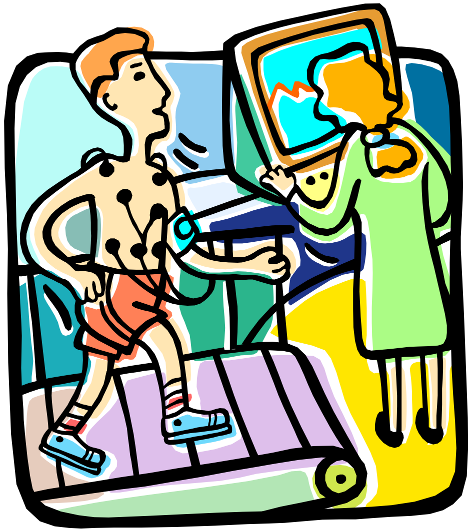
- The battery life also depends on the number of electrical shocks it sends to the heart.
  - Unnecessary shocks waste battery life and can be detrimental to the patient’s health.

- Typical ICDs today are designed to have a battery life of approximately nine years.

The patient should only receive treatments when necessary, those shocks can hurt!

- The detection algorithm must be complex enough to be accurate.

- The heart rhythm from exercise can look very similar to the fast rhythm of a cardiac arrhythmia.



Algorithms must detect arrhythmias in real time.

- The algorithm must be able to correctly distinguish between VT, SVT and exercise.
  - VT are dangerous and require electrical shock therapy.
  - SVT and exercise are not dangerous and do not need therapy.

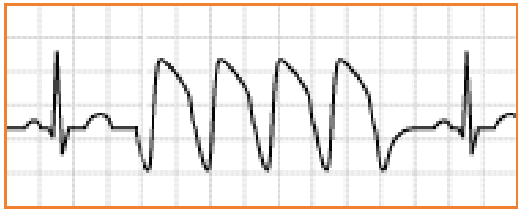
- The algorithm must be complex enough to distinguish between these but not so complex that it is too slow and uses too much battery life.

- Balance is key!

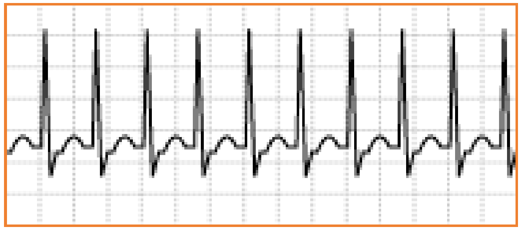
Our Project

- Develop a MATLAB program to analyze actual electrocardiogram (ECG) signals and determine whether they are dangerous, life-threatening ventricular tachycardias (VT) or the more benign supraventricular tachycardias (SVT).

VT



SVT

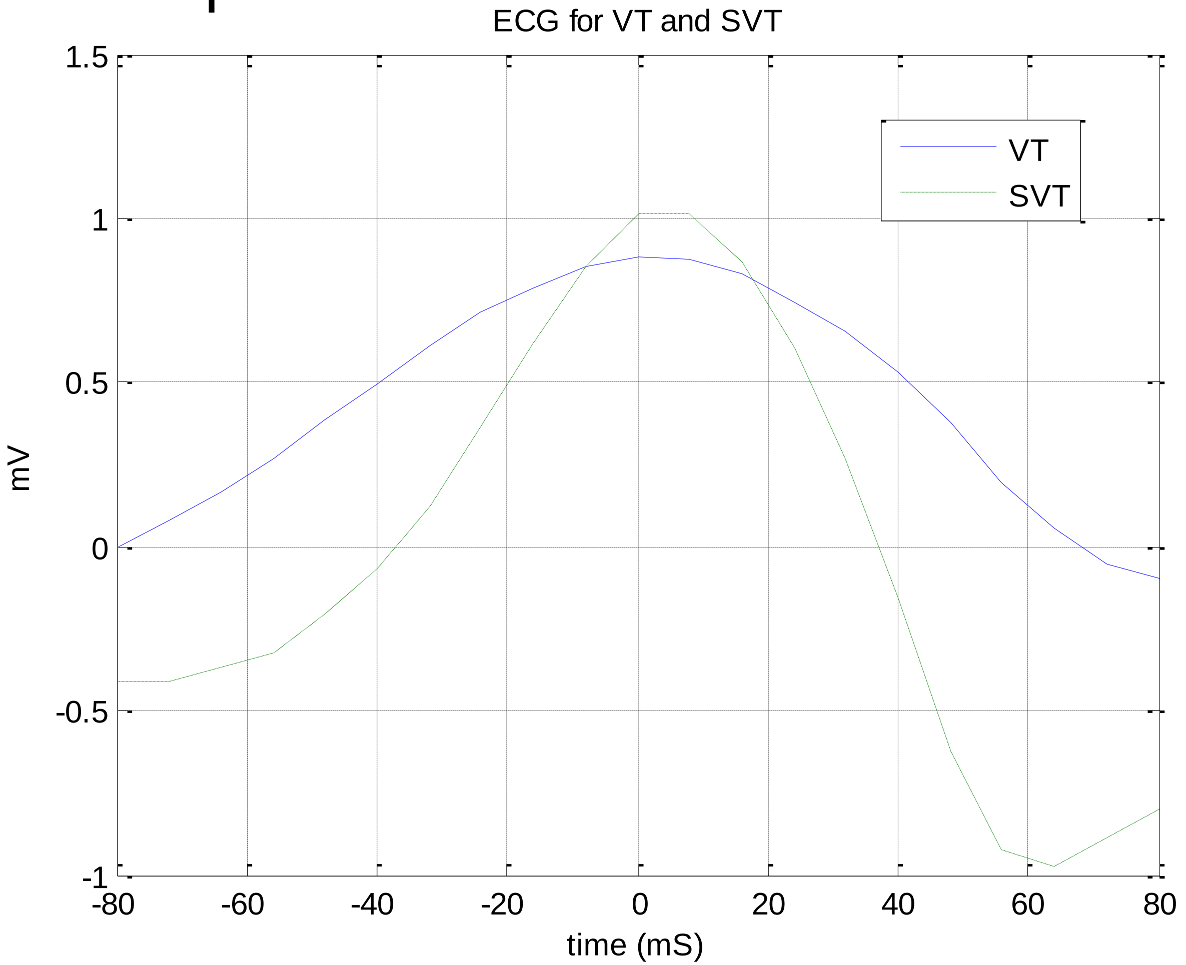


Cardiologists are trained to classify ECGs as either VT (requires treatment) or SVT (doesn’t require treatment). We need to create an algorithm that allows the ICD to do what a doctor would do.

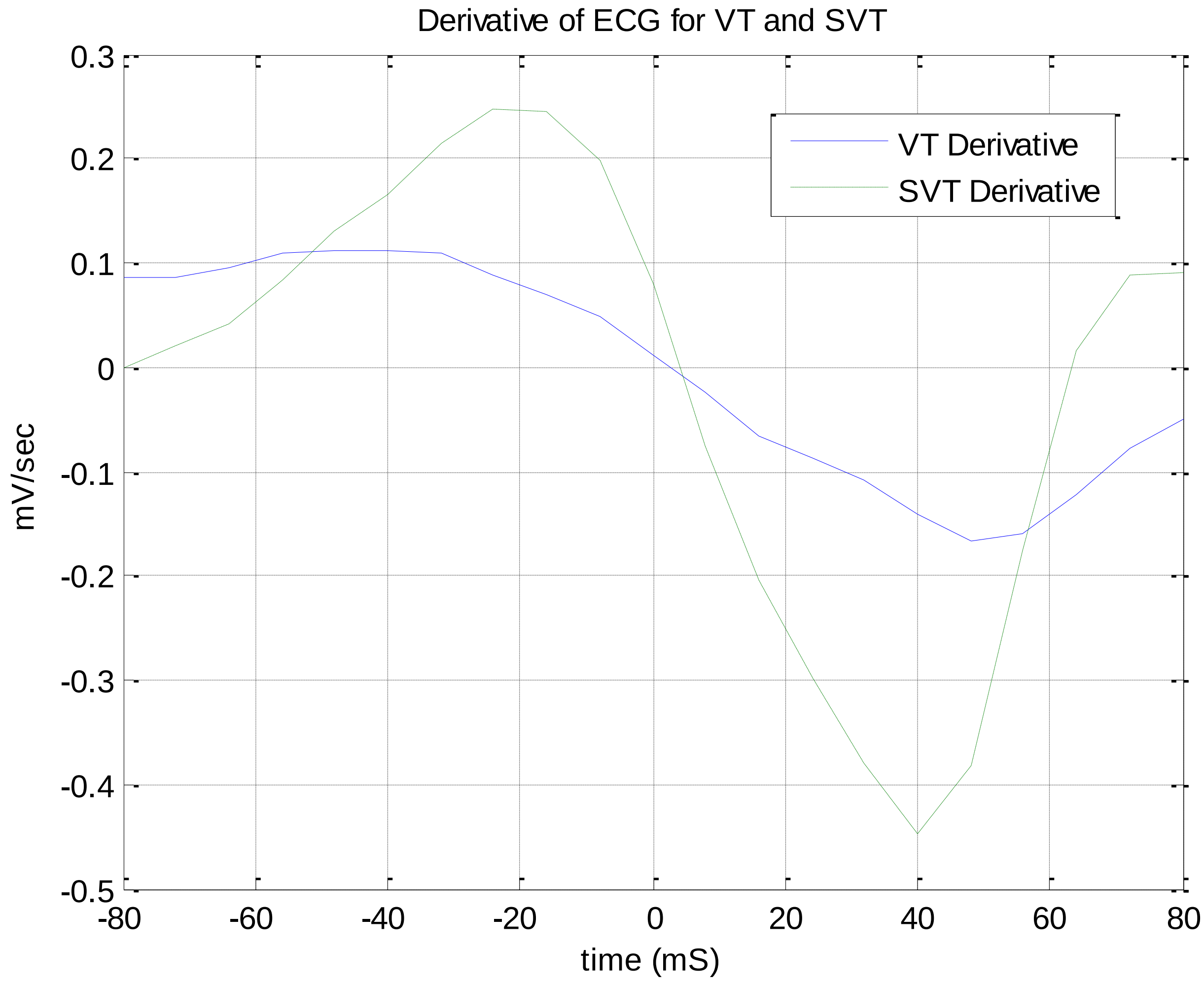
- The algorithm must be able to differentiate between different types of arrhythmias (VT and SVT).

- The algorithm must be accurate enough to safely replace the intuition and experience that doctors possess.

Let's zoom in to the 80 mS before and after the QRS pulse in an ECG from VT and SVT. What is difference between these pulses?

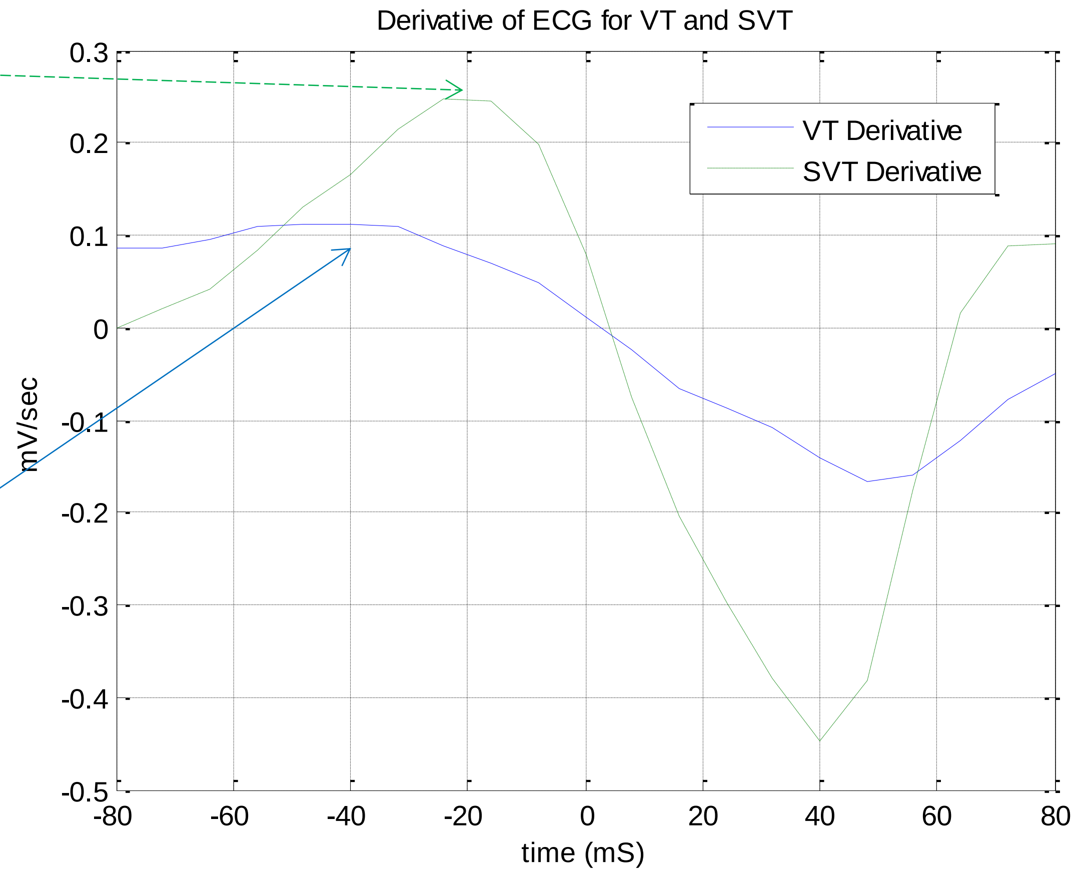


Let's also look at the **derivative** of the QRS pulse for VT and SVT.



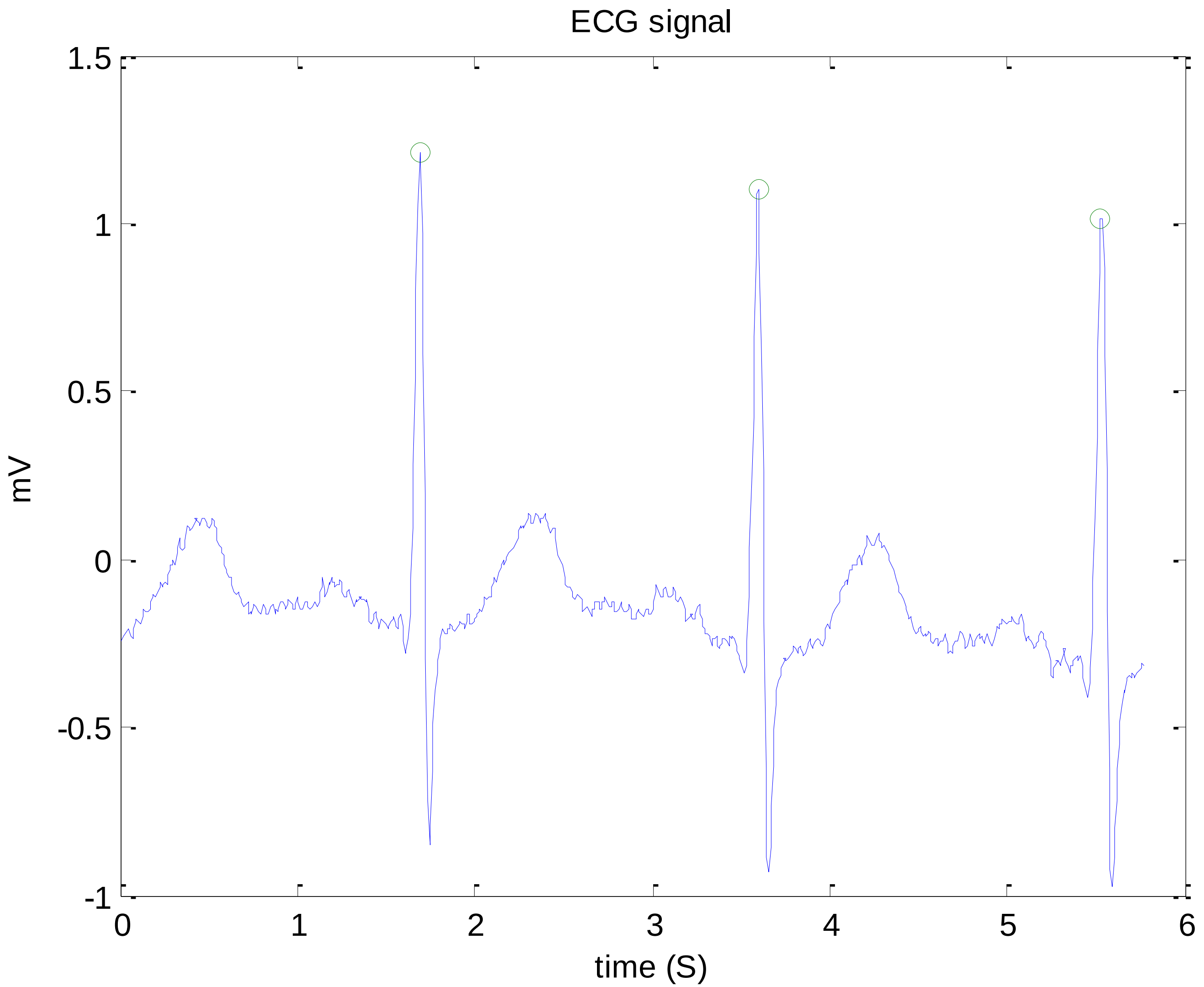
The time of the first peak (called the onset time) in the derivative of the ECG signal tends to occur sooner for VT than in SVT

SVT
First peak
at -20mS



VT
First peak
at -40mS

Each of the ECG test signals in this project have three peaks. The program needs to detect all three.



Overview of the Derivative Method

- Locate the three peaks from one of the ECG signals
- Extract the 80ms interval before each peak
- Calculate the derivative of each of the three 80ms intervals
- Compute the average of the three derivatives
- Find the time of the first peak in the average signal (onset time)
- If the onset time is less than a certain threshold value (to be determined), classify as VT and print ‘VT (Treatment needed!!)’
- If the time is greater than a certain threshold value, classify as SVT and print ‘SVT (No treatment needed)’

After the onset times for all of the known signals have been computed, calculate the threshold value as follows:

$$threshold = \frac{(\max onset\ time\ VT) + (\min onset\ time\ SVT)}{2}$$

ECG Signal Name	Classification	Onset Time (ms)
vt1	VT	-72
vt2	VT	-32
vt3	VT	
vt4	VT	
vt5	VT	
svt1	SVT	-24
svt2	SVT	-24
svt3	SVT	
svt4	SVT	
svt5	SVT	

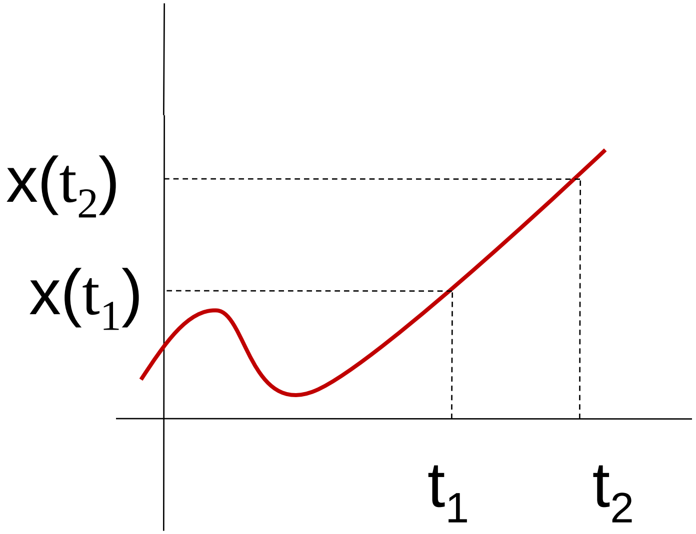
Then use this threshold to classify the *unknown* ECG signals!

NOTE: our ECG signals are from patients and have been classified by cardiologists

How to Load the Data

- Download the file “ECG_data.zip” from the course website, and unzip the files
- Load the file ECG_data.mat into MATLAB using the following command:
  - load ECG_data.mat
- The following variables are included in the file:
  - T: sampling interval (0.008 Sec or 8 mS)
  - vt1 through vt5: known signals classified as VT
  - svt1 through svt5: known signals classified as SVT
  - unknown1 through unknown9: Unknown signals for you to classify

How to compute the derivative (slope) of a discrete-time signal.



$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{x(t_2) - x(t_1)}{t_2 - t_1}$$

We can use the MATLAB function `gradient` to compute the derivative of a signal.

How to locate the peaks

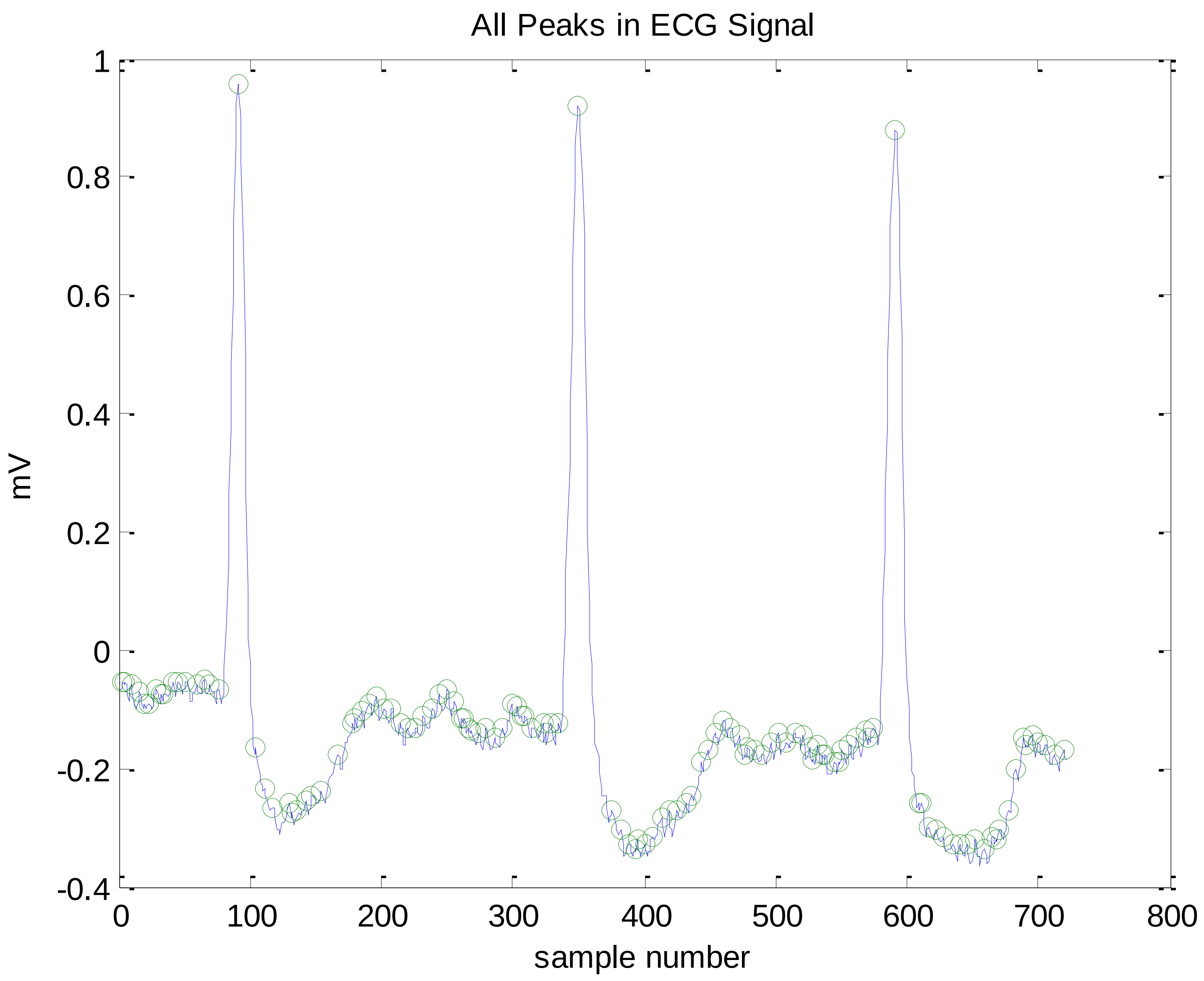
- The MATLAB function `findpeaks` will return the location of the peaks.

- Example (finds all of the peaks):

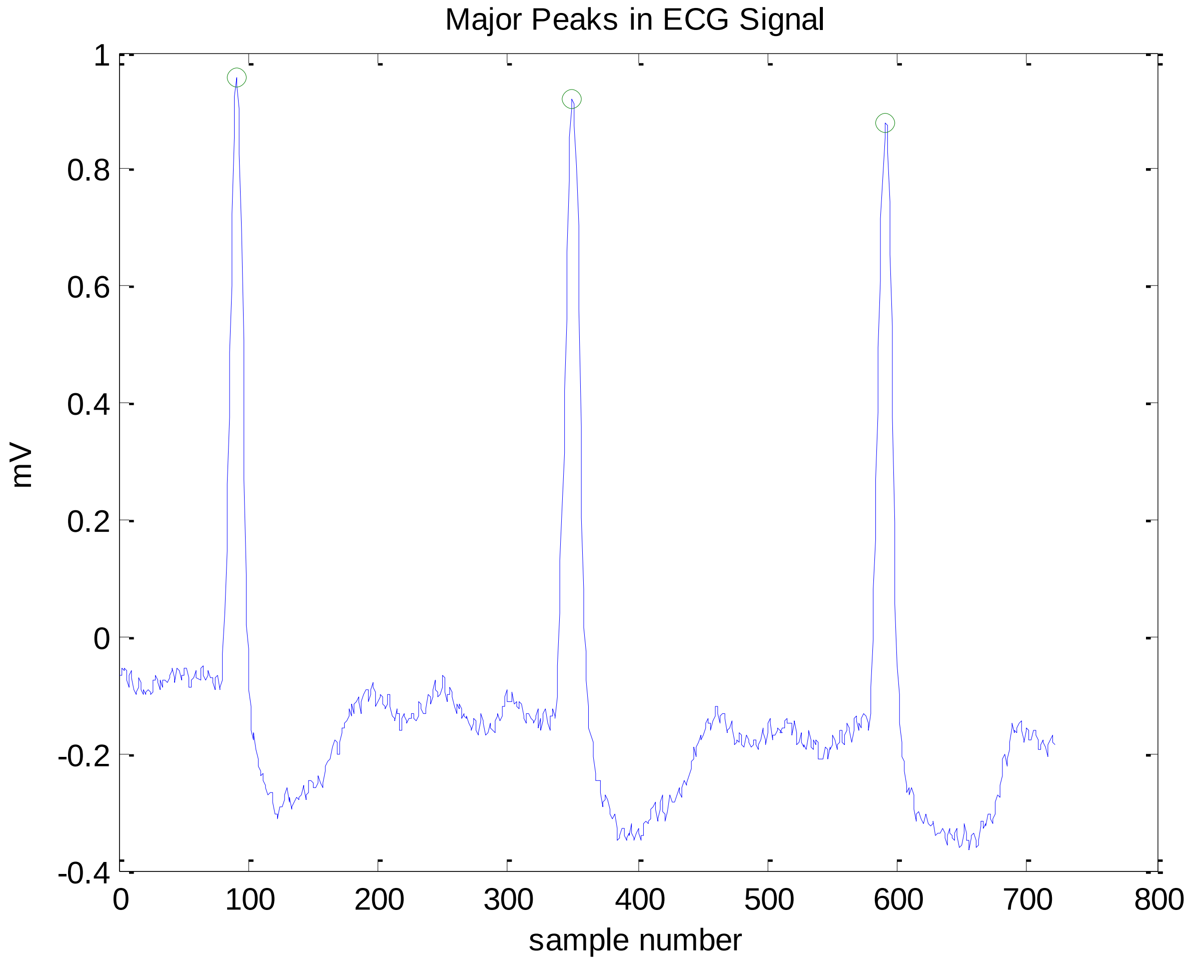
```
load ECG_data.mat
[p,in] = findpeaks(vt3);
ind = 1:length(x);
plot(in,x,ind(in),x(in),'o')
```

- See the plot on next slide…

Too Many Peaks!



The `findpeaks` command can limit the peaks to those above a minimum height (MINPEAKHEIGHT) and those that are more than a minimum distance from each other (MINPEAKDISTANCE) so that it only returns the three largest peaks. See the help file for details.



The `mean` command can be used to compute the mean of several vectors.

Example (row vectors):

```
>> x1 = [1 2 3];
>> x2 = [4 5 6];
>> mean([x1; x2])
ans =
   2.50   3.50   4.50
```

Example (column vectors):

```
>> x1 = [1; 2; 3];
>> x2 = [4; 5; 6];
>> mean([x1 x2], 2)
ans =
      2.50
      3.50
      4.50
```

How to Proceed

- Load the data
- Graph a few of the ECG signals to examine them
- Write a function to compute the onset time of an ECG signal
- Compute the onset time for the known signals (vt1 through vt5 and svt1 through svt5)
- Compute the threshold value
- Write a function that classifies an ECG signal, and test it on the known signals
- Classify the unknown signals

Let us know if you have any questions.