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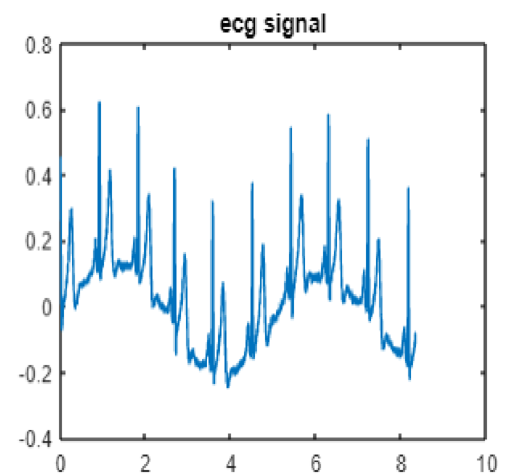
Final Project – Biomedical Engineering

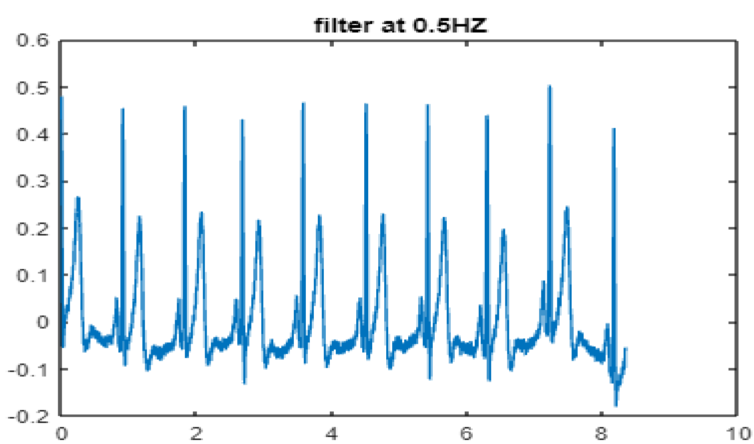
1.Ecg signal:

```
clear all;
close all;
clc;
load("ecg.mat");
fs=500;
%sampling
t=1:1:length(ecg);
T=0:1/fs:length(ecg);
figure
plot(T(t),ecg(t));
title('ecg signal');
```

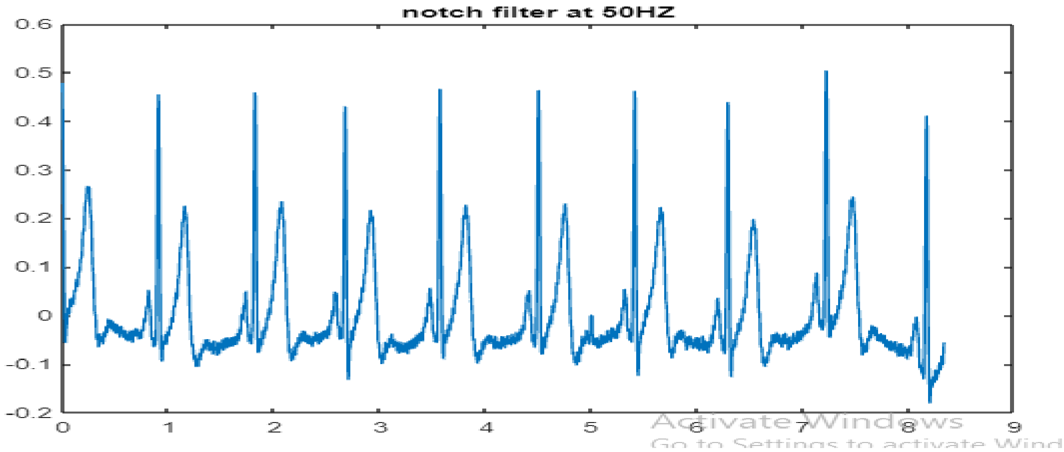


The signal has been sampled with a frequency of 500 Hz

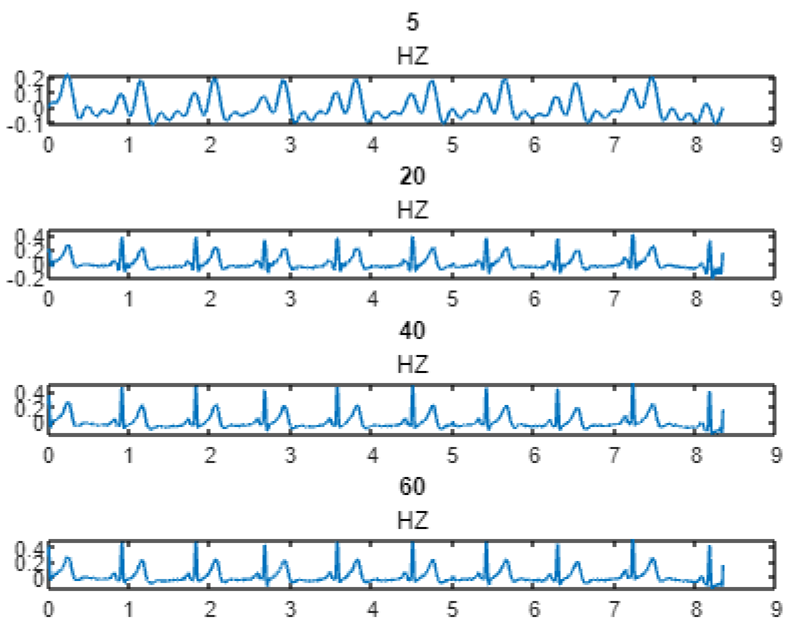
set frequencies below 0.5 Hz to zero:

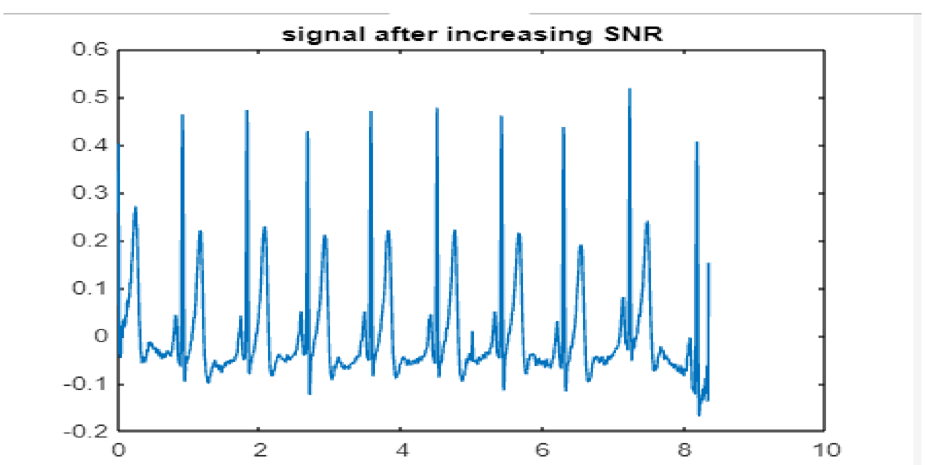


2.Notch filter at 50HZ



3. Increasing the signal-to-noise ratio:





A higher bandwidth will give more noise in the signals,

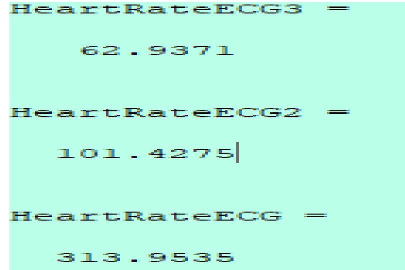
and limiting the bandwidth can obscure details in the ECG.

a compromise on the cutt f freq we choose 5.99(50) almost 6 HZ filter

to not details in the ecg without give more noise.

4. Finding the heart rate using autocorrelation:

The processed signal has less heart rate than the unprocessed signal.


HeartRateECG3 =

62.9371

HeartRateECG2 =

101.4275

HeartRateECG =

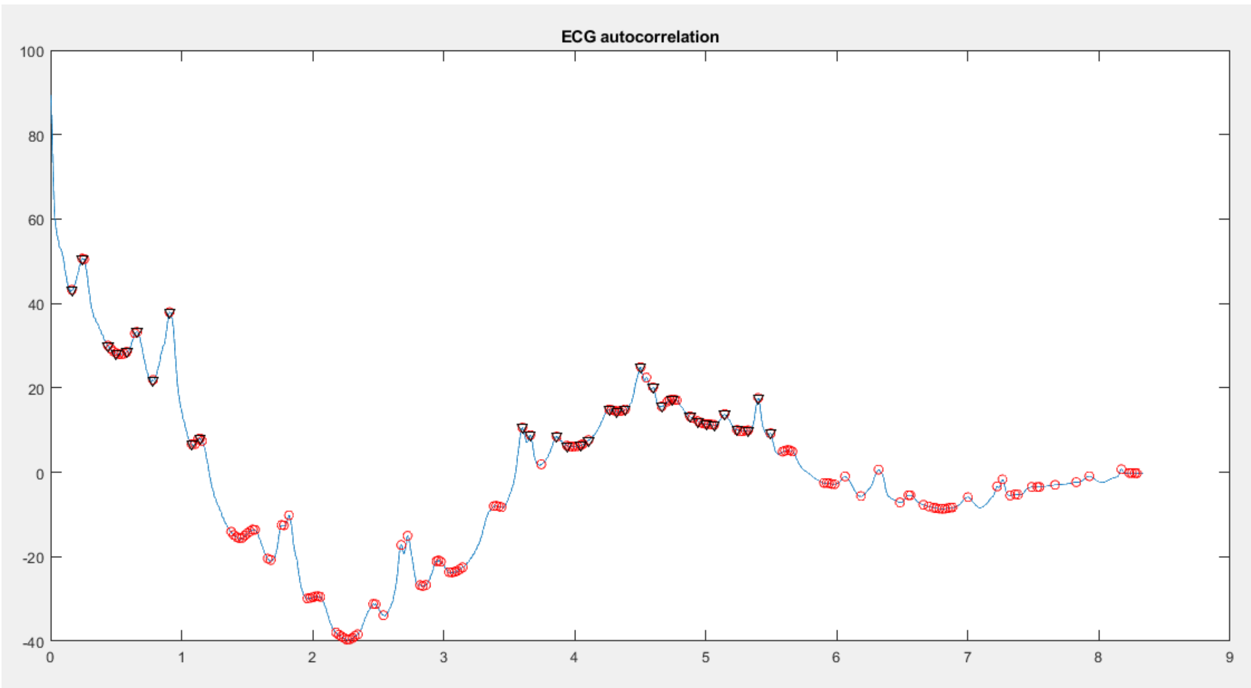
313.9535

HeartRateECG = 313.9535

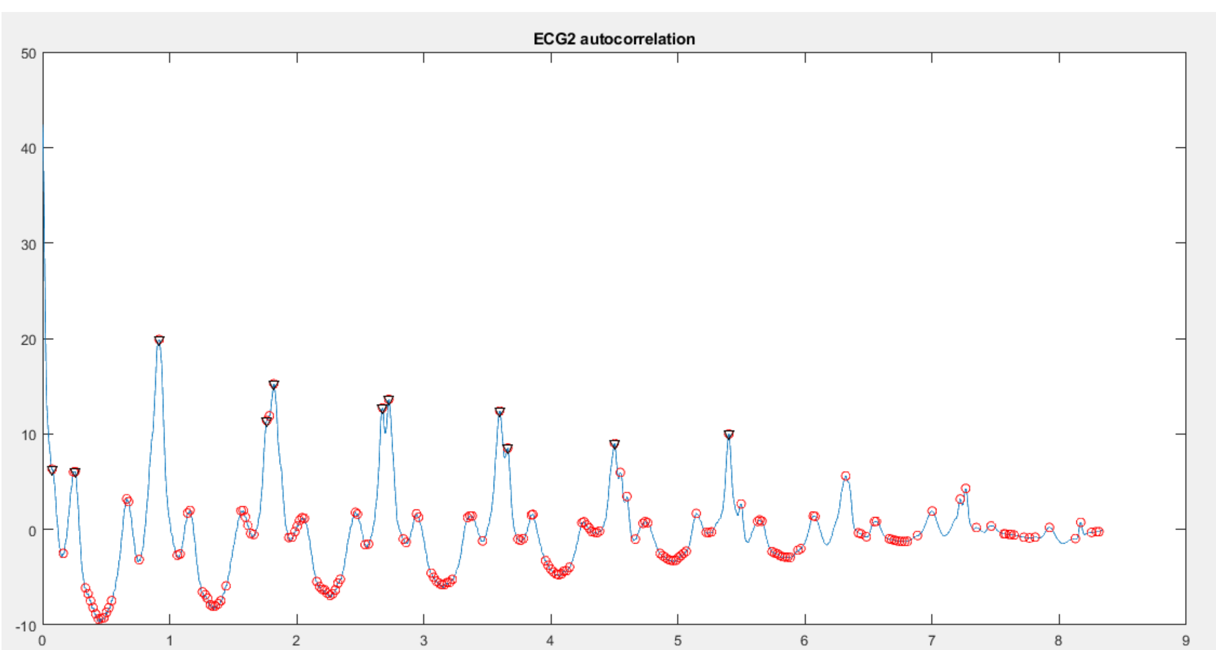
HeartRateECG2 = 101.4275

HeartRateECG3 = 62.9371

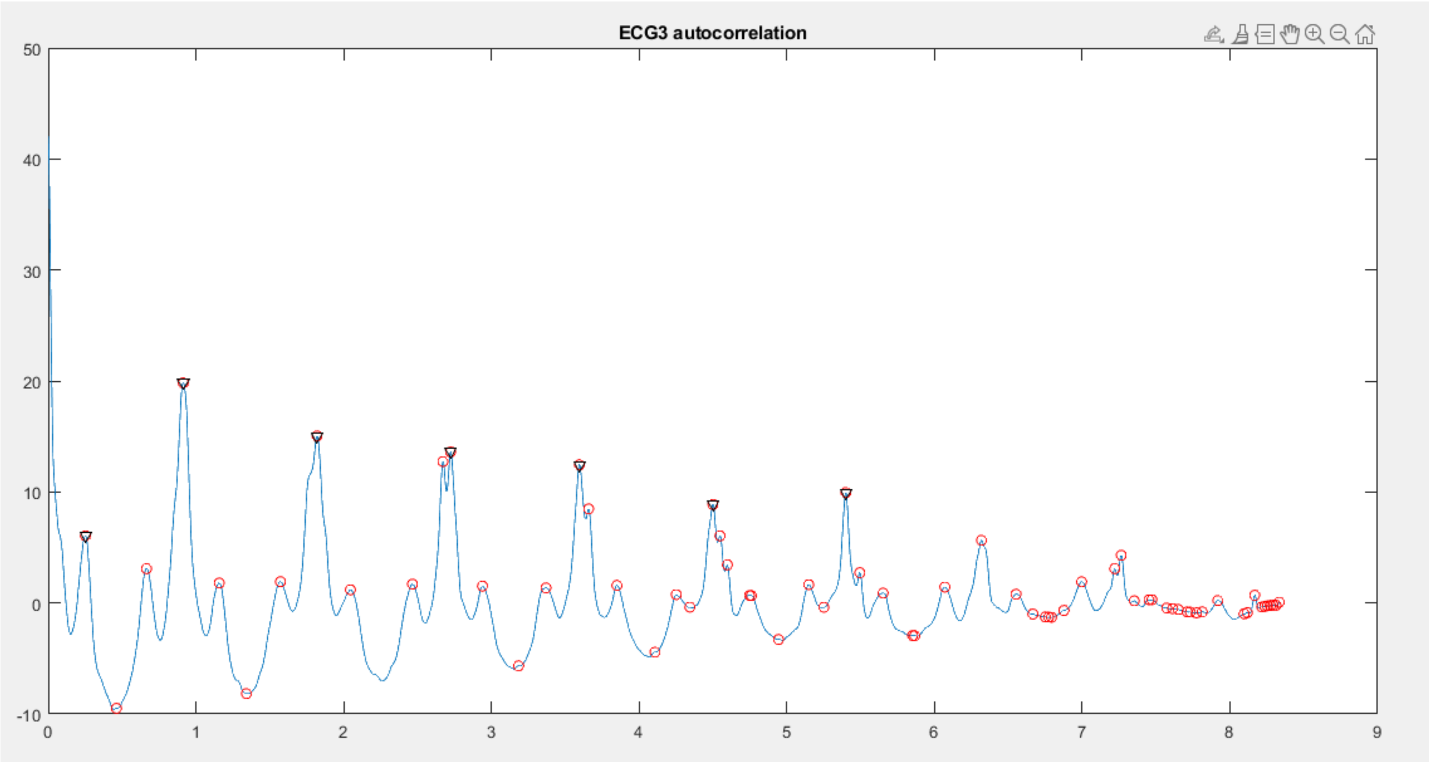
1. Ecg:



2. Ecg2:



3. Ecg3:



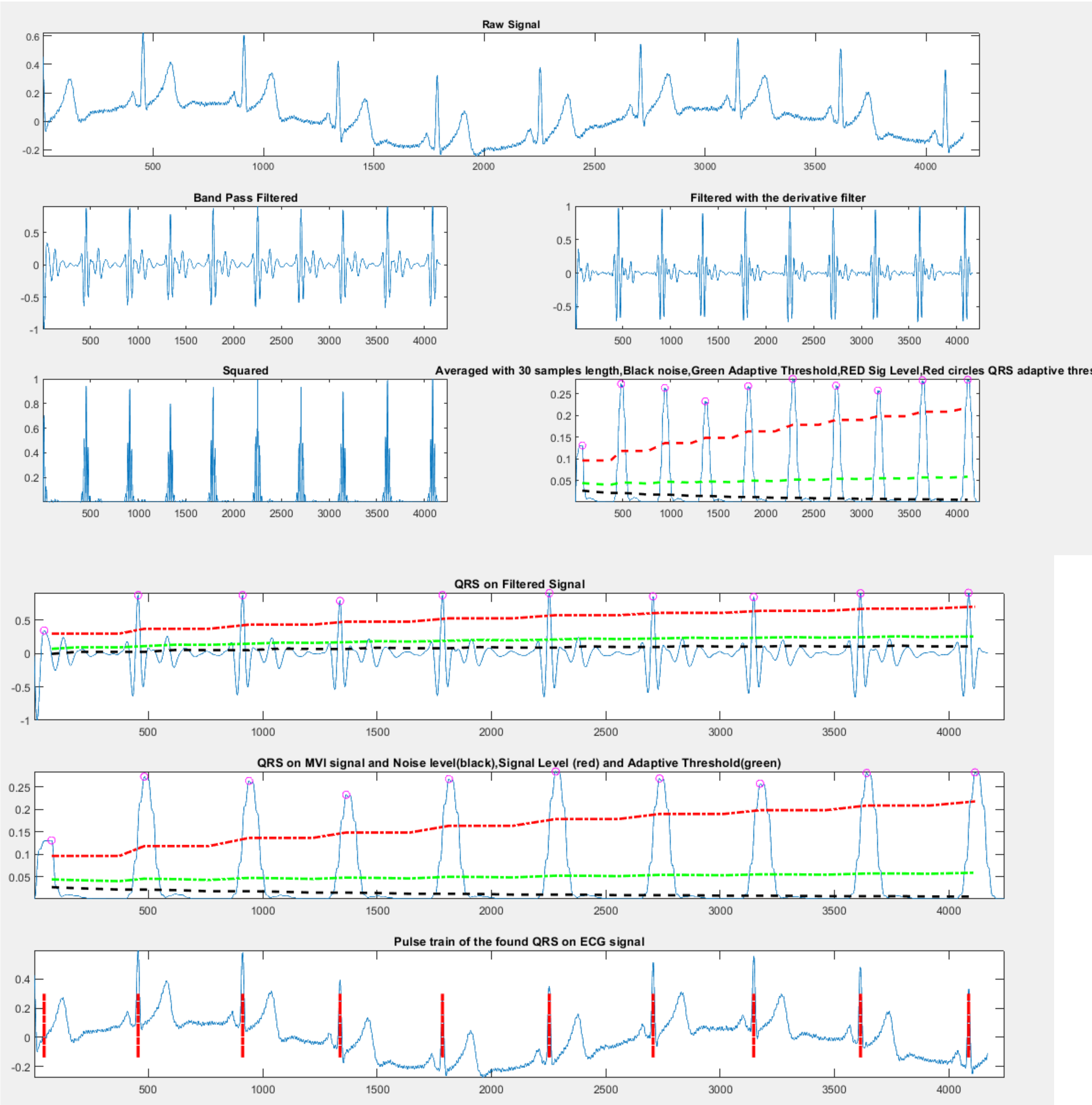
The autocorrelation heart rate code:

```
%% Asmaa's part
%-------- 4. Finding the heart rate using autocorrelation -----------------
AdultRate=90;
%ecg3
figure (6)
ecg3norm = ecg3 - mean(ecg3);
[autocor,lags] = xcorr(ecg3norm,ecg3norm);
autocor=autocor(round(length(autocor)/2):end);
lags=lags(round(length(lags)/2):end);

[peakShort,locationShort] = findpeaks(autocor);
short = mean(diff(locationShort))/fs;
[RRpeak,locationR] =
findpeaks(autocor,'MinPeakDistance',ceil(short*fs),'MinPeakheight',6);
RRinterval = mean(diff(locationR))/(0.6*fs);

HeartRateECG3=AdultRate/RRinterval

plot(lags/fs,autocor);
hold on
plot(lags(locationShort)/fs,peakShort,'or', lags(locationR)/fs,RRpeak,'vk');
title('ECG3 autocorrelation')

%ecg2
figure (7)
ecg2norm = ecg2 - mean(ecg2);
[autocor,lags] = xcorr(ecg2norm,ecg2norm);
autocor=autocor(round(length(autocor)/2):end);
lags=lags(round(length(lags)/2):end);
```

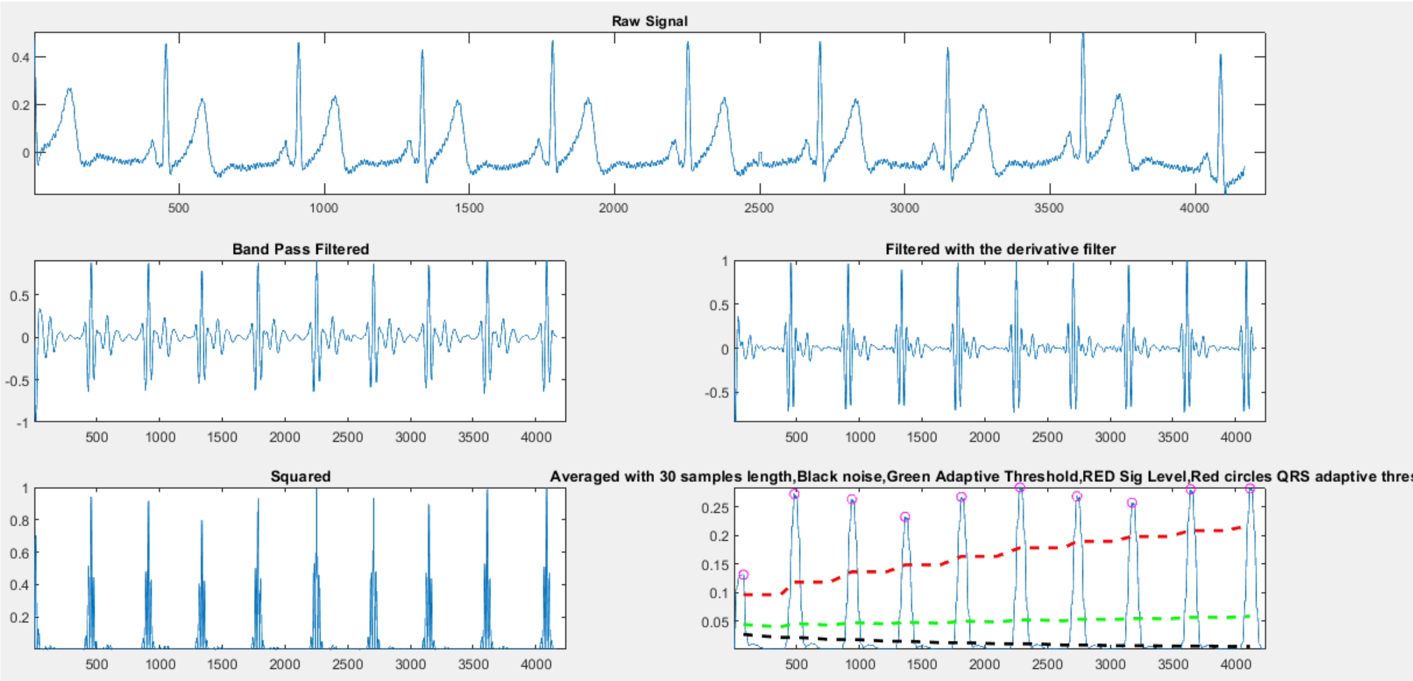
```
[peakShort,locationShort] = findpeaks(autocor);
short = mean(diff(locationShort))/fs;
[RRpeak,locationR] =
findpeaks(autocor,'MinPeakDistance',ceil(short*fs),'MinPeakheight',6);
RRinterval = mean(diff(locationR))/(0.6*fs);

HeartRateECG2=AdultRate/RRinterval

plot(lags/fs,autocor);
hold on
plot(lags(locationShort)/fs,peakShort,'or', lags(locationR)/fs,RRpeak,'vk');
title('ECG2 autocorrelation')

%ecg
figure (8)
ecgnorm = ecg - mean(ecg);
[autocor,lags] = xcorr(ecgnorm,ecgnorm);
autocor=autocor(round(length(autocor)/2):end);
lags=lags(round(length(lags)/2):end);

[peakShort,locationShort] = findpeaks(autocor);
short = mean(diff(locationShort))/fs;
[RRpeak,locationR] =
findpeaks(autocor,'MinPeakDistance',ceil(short*fs),'MinPeakheight',6);
RRinterval = mean(diff(locationR))/(0.6*fs);
HeartRateECG=AdultRate/RRinterval


plot(lags/fs,autocor);
hold on
plot(lags(locationShort)/fs,peakShort,'or', lags(locationR)/fs,RRpeak,'vk');
title('ECG autocorrelation')
```

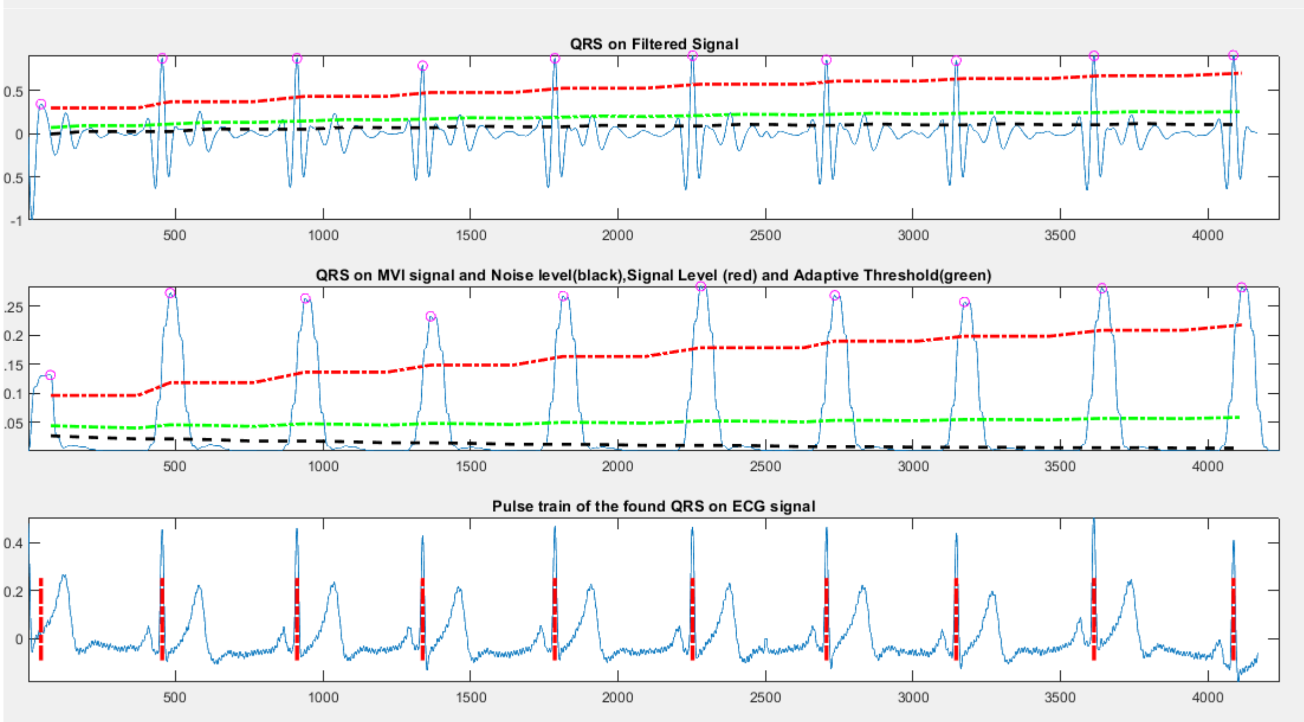
5. Finding the QRS complex:

1. Ecg:

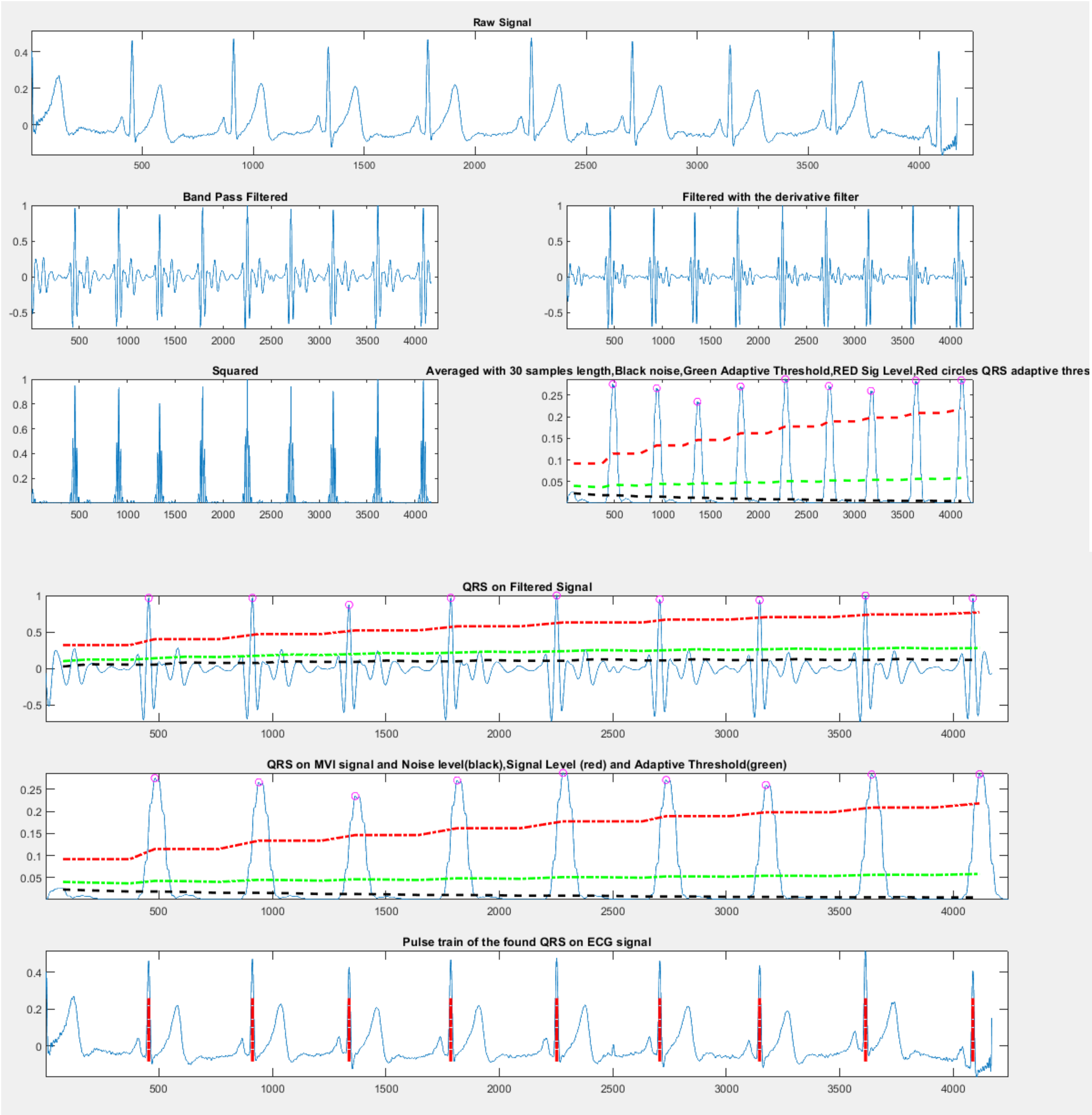


2. Ecg2:


Raw Signal
Band Pass Filtered
Filtered with the derivative filter
Squared
Averaged with 30 samples length,Black noise,Green Adaptive Threshold,RED Sig Level,Red circles QRS adaptive thres


QRS on Filtered Signal
QRS on MVI signal and Noise level(black),Signal Level (red) and Adaptive Threshold(green)
Pulse train of the found QRS on ECG signal

3. Ecg3:



Raw Signal
Band Pass Filtered
Filtered with the derivative filter
Squared
Averaged with 30 samples length,Black noise,Green Adaptive Threshold,RED Sig Level,Red circles QRS adaptive thres
QRS on Filtered Signal
QRS on MVI signal and Noise level(black),Signal Level (red) and Adaptive Threshold(green)
Pulse train of the found QRS on ECG signal

The QRS code:

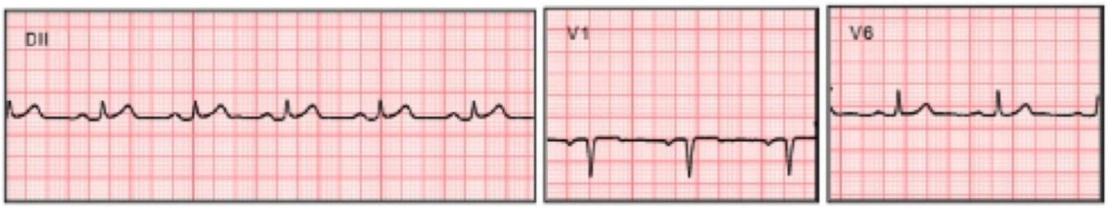
```
%% conintuing of Asmaa's part
%-------- 5. Finding the QRS complex: -----------------

figure ;
pan_tompkin(ecg, fs,1);

figure;
pan_tompkin(ecg2, fs,1);

figure;
pan_tompkin(ecg3, fs,1);

%{
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% the detailed solution with steps %%%%%%%%%%%
if ~isvector(ecg)
  error('ecg must be a row or column vector');
end

gr = 1;   % on default the function always plots

ecg = ecg(:); % vectorize

% ======================= Initialize =============================== %
delay = 0;
skip = 0;                                                          % becomes one
when a T wave is detected
m_selected_RR = 0;
mean_RR = 0;
ser_back = 0;
ax = zeros(1,6);

% ============ Noise cancelation(Filtering)( 5-15 Hz) =============== %%
if fs == 200
% ------------------ remove the mean of Signal -----------------------%
  ecg = ecg - mean(ecg);
% ==== Low Pass Filter  H(z) = ((1 - z^(-6))^2)/(1 - z^(-1))^2 ==== %%

   Wn = 12*2/fs;
   N = 3;                                                          % order of 3
less processing
   [a,b] = butter(N,Wn,'low');                                     % bandpass
filtering
   ecg_l = filtfilt(a,b,ecg);
   ecg_l = ecg_l/ max(abs(ecg_l));
 % ======================= start figure ============================= %%

    figure;
    ax(1) = subplot(321);plot(ecg);axis tight;title('Raw signal');
    ax(2)=subplot(322);plot(ecg_l);axis tight;title('Low pass filtered');

% ==== High Pass filter H(z) = (-1+32z^(-16)+z^(-32))/(1+z^(-1)) ==== %%
   Wn = 5*2/fs;
   N = 3;                                                          % order of 3
less processing
   [a,b] = butter(N,Wn,'high');                                    % bandpass
filtering
   ecg_h = filtfilt(a,b,ecg_l);
```

```
   ecg_h = ecg_h/ max(abs(ecg_h));

    ax(3)=subplot(323);plot(ecg_h);axis tight;title('High Pass Filtered');

else
% bandpass filter for Noise cancelation of other sampling frequencies(Filtering)
 f1=5;                                                                            % cuttoff low
frequency to get rid of baseline wander
 f2=15;                                                                           % cuttoff
frequency to discard high frequency noise
 Wn=[f1 f2]*2/fs;                                                                 % cutt off
based on fs
 N = 3;                                                                           % order of 3
less processing
 [a,b] = butter(N,Wn);                                                            % bandpass
filtering
 ecg_h = filtfilt(a,b,ecg);
 ecg_h = ecg_h/ max( abs(ecg_h));

  ax(1) = subplot(3,2,[1 2]);plot(ecg);axis tight;title('Raw Signal');
  ax(3)=subplot(323);plot(ecg_h);axis tight;title('Band Pass Filtered');

end
% ==================== derivative filter ========================== %%
% ------ H(z) = (1/8T)(-z^(-2) - 2z^(-1) + 2z + z^(2)) --------- %
if fs ~= 200
 int_c = (5-1)/(fs*1/40);
 b = interp1(1:5,[1 2 0 -2 -1].*(1/8)*fs,1:int_c:5);
else
 b = [1 2 0 -2 -1].*(1/8)*fs;
end

 ecg_d = filtfilt(b,1,ecg_h);
 ecg_d = ecg_d/max(ecg_d);

  ax(4)=subplot(324);plot(ecg_d);
  axis tight;
  title('Filtered with the derivative filter');

% ========== Squaring nonlinearly enhance the dominant peaks ========== %%
 ecg_s = ecg_d.^2;

  ax(5)=subplot(325);
  plot(ecg_s);
  axis tight;
  title('Squared');



%============  Moving average ================== %%
%-------Y(nt) = (1/N)[x(nT-(N - 1)T)+ x(nT - (N - 2)T)+...+x(nT)]---------%
ecg_m = conv(ecg_s ,ones(1 ,round(0.150*fs))/round(0.150*fs));
delay = delay + round(0.150*fs)/2;



  ax(6)=subplot(326);plot(ecg_m);
  axis tight;
  title('Averaged with 30 samples length,Black noise,Green Adaptive Threshold,RED Sig
Level,Red circles QRS adaptive threshold');
  axis tight;
%}
```

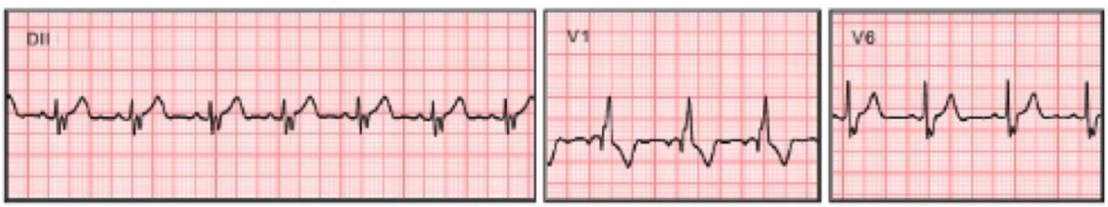
6. ECG heart diseases Survey With Figures:

No abnormalities

1st degree AV block (1dAVb)



Right bundle branch block (RBBB)



Left bundle branch block (LBBB)

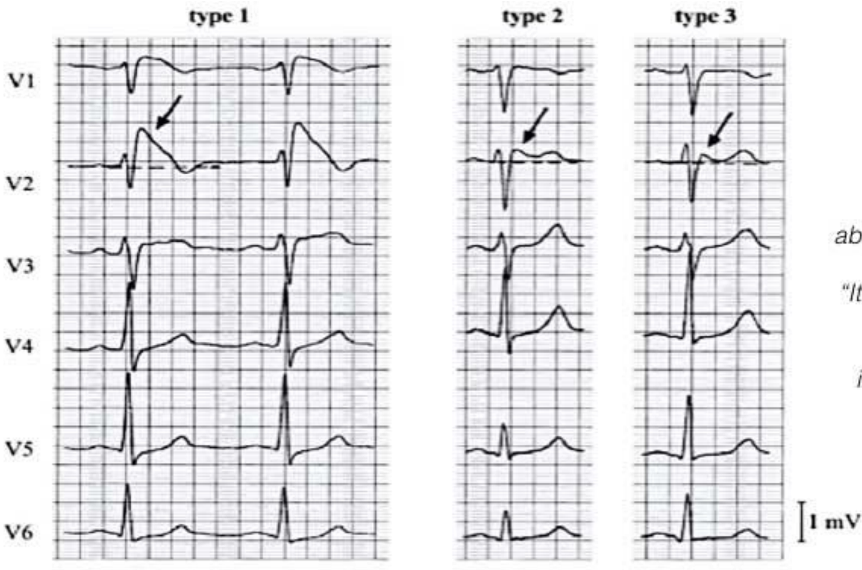
Sinus bradycardia (SB)

Atrial fibrillation (AF)

Sinus tachycardia (ST)

Brugada Syndrome

Brugada Syndrome is a rare inherited cardiac arrhythmia syndrome that is characterised by a 'coved-shaped' atypical right bundle branchpattern on a 12-lead ECG (Type-1 Brugada pattern ECG) and is associated with ventricular arrhythmias and sudden cardiac death. Brugada Syndrome is reported to be responsible for 4% of all sudden deaths and 20% of sudden deaths in those without structural heart disease.



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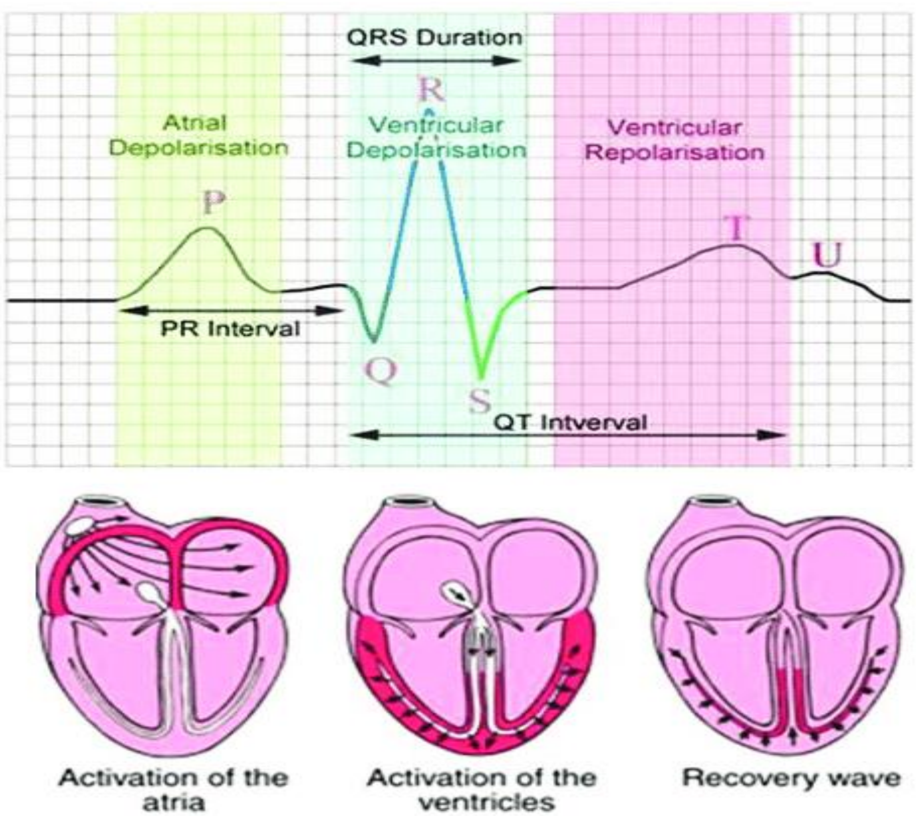
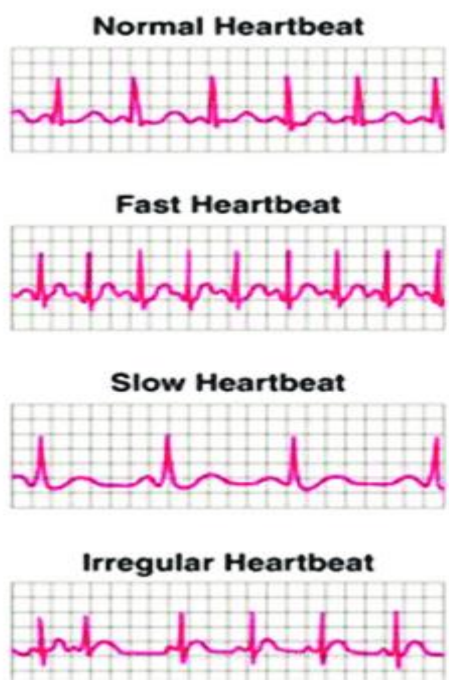
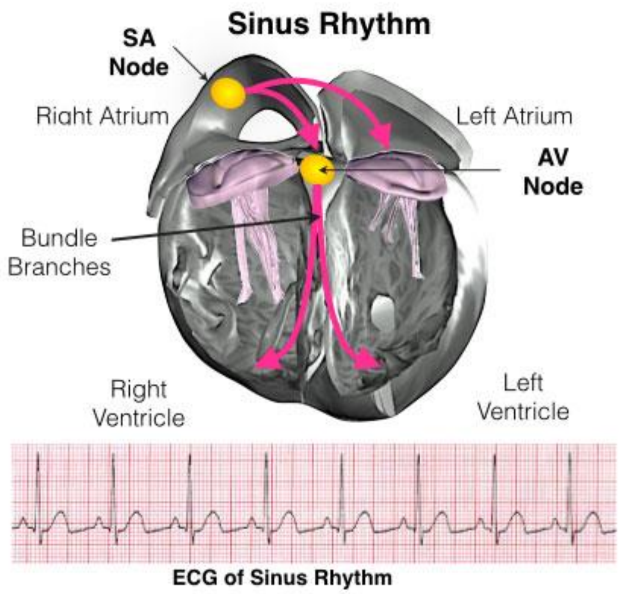
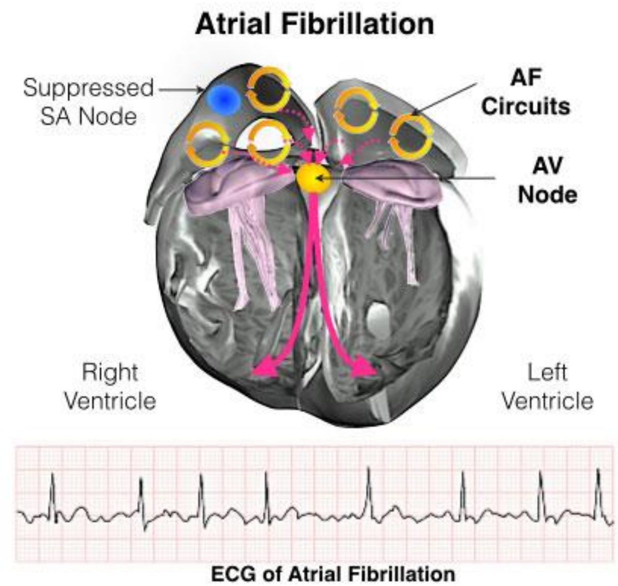
*"**Brugada Syndrome** is due to an abnormality in the cardiac sodium channel"*

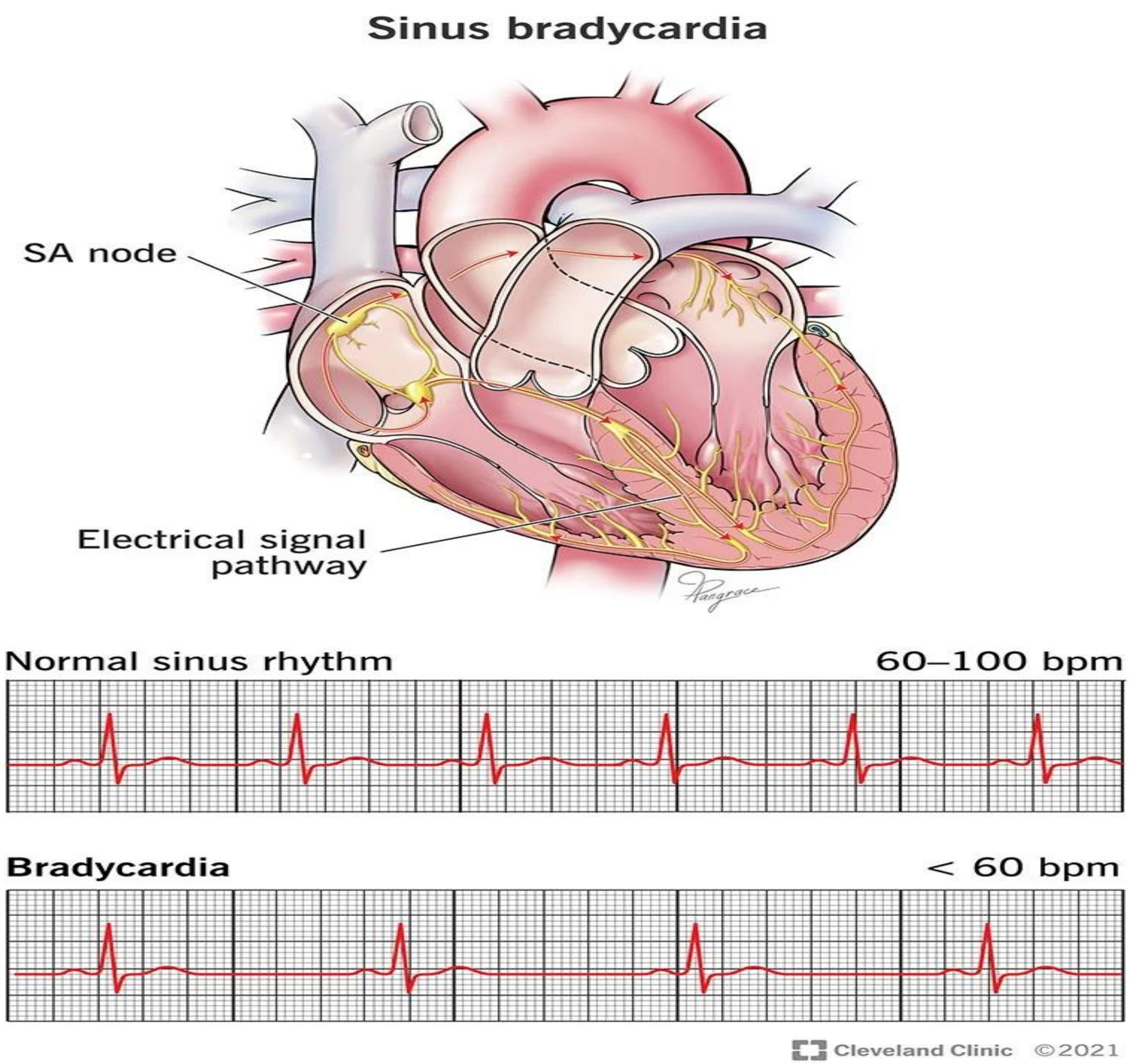
"It leads to a classical ECG appearance of an atypical right bundle branch block pattern with 'coved' ST elevation in ECG leads V_1 to V_3. (Type 1 pattern)"





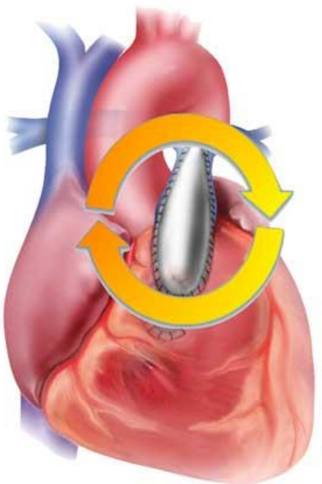

Sinus Rhythm
SA Node
Right Atrium
Left Atrium
AV Node
Bundle Branches
Right Ventricle
Left Ventricle
ECG of Sinus Rhythm


Atrial Fibrillation
Suppressed SA Node
AF Circuits
AV Node
Right Ventricle
Left Ventricle
ECG of Atrial Fibrillation

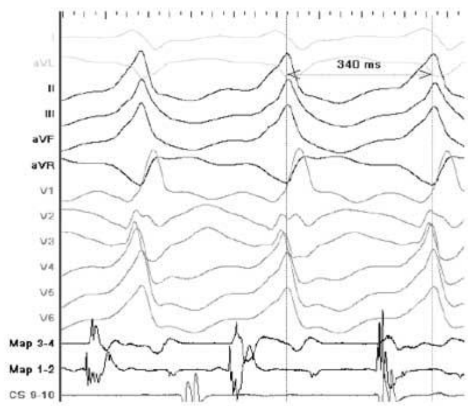

Sinus bradycardia
SA node
Electrical signal pathway
Normal sinus rhythm
60–100 bpm
Bradycardia
< 60 bpm
Cleveland Clinic ©2021

Ventricular Tachycardia in Structural Heart Disease

VT circuit revolving around a patch after a Tetraology of Fallot Repair



Electrical signals during the case



"Patients with surgically corrected congenital heart disease can also develop problems with VT.

These circuits are often related to the the original surgery . Commonly they will involve reentry circuits revolving around either scar tissue, surgical suture lines or surgical patches."

Heat energy is delivered via the Ablation catheter

Electrical Information from catheters in the heart. The green arrows show the electrical signal from the important channel causing this VT.

"We map the scar with the catheter to find the important muscle channels that are causing the VT. We then use heat energy to ablate (cauterise) the tissue to stop the circuits from re-forming"

"There will be often multiple VT circuits within the same heart that will require ablation"

Schematic of VT circuit

Ablation catheter used to map VT

Electrical Information from catheters inside the heart.

"VT is caused by large circuits revolving around islands of scar tissue (grey). The most important part of the VT circuit are the channels of surviving tissue (green arrows) separating islands of scar tissue"

"During a VT ablation we pass an ablation catheter from the leg to the left ventricles to find these critical channels."